BURO HAPPOLD

Design Note

Project	Net Zero Terrace SIF – Alpha, M4, D6
Subject	Techno-Economic Model
Deliverable	M4 D6 Techno Economic Model
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00	Draft for Review	AD	27/03/2024	PP

Contents

Glossary

Term	Definition
CAPEX	Capital Expenditure
CEMS	Community Energy Management System
COP	Coefficient of Performance
DESNZ	Department for Energy Security and Net Zero
NPV	Net Present Value
NZT	Net Zero Terrace
OPEX	Operational Expenditure
PPA	Private Purchase Agreement
PV	Photo Voltaic
REPEX	Replacement Expenditure
SIF	Strategic Innovation Fund
SPV	Special Purpose Vehicle
TEM	Techno-Economic Model
UK	United Kingdom
UKIB	UK Infrastructure Bank

1 Introduction

This design note presents the techno-economic model (TEM) developed as part of the Net Zero Terrace (NZT) Alpha stage. The techno-economic model has been restructured from the discovery stage to progress towards the aim of national deployment. The purpose of the model developed is to assess the economic feasibility and sensitivities to commercially deploy the NZT scheme. The TEM will look at the costs of deploying the net zero terrace scheme at scale and to establish the costs and grant funding required to deploy to a 10-home demonstrator.

The TEM is designed to take a number of inputs including the estimated capital costs, operating costs, replacement expenditure and the cost of finance. The economic viability of the scheme under different scenarios will then be determined. This could include the utilisation of grant funding. The TEM can also be used to explore economies of scale and the use of surplus generated to reduce costs for consumers can be explored. Realistic cost estimates and tariff estimates will be obtained through working with suppliers. It should be noted that the TEM is not a financial tool and should not be used to make investment decisions.

The TEM will capture both the costs to consumers and the revenue to the special purpose vehicle. The commercial structures and workflows will define how both stakeholders work together.

The key aim of the techno-economic model is to assess the feasibility of deploying Net Zero Terrace at scale while providing an affordable solution to residents. Energy prices paid by consumers through Net Zero Terrace should continue to be affordable. The TEM will calculate the total annual bills payable by consumers, which will include a standing charge and an electricity tariff and compare these to consumers energy bills. The TEM will also capture the revenue made by the SPV and use cases for the revenue will be explored in this report.

It should be noted that at this stage a number of costs are assumed and will need to be determined but have been used to test the model and how sensitivity it is to those inputs. Therefore, the outputs of the model should be considered in that context and in preparation for refinement in the Beta stage.

2 Model Overview

The below sections introduce the commercial structure developed for NZT as modelled in the TEM, the intendencies between the TEM and other models and the scenarios modelled in the TEM.

2.1 Commercial structure

The commercial structure for the Net Zero Terrace scheme is shown below in Figure 2-1. The commercial structure considers two main stakeholders: the special purpose vehicle (SPV), which delivers the scheme and provides the service. and the NZT residents, i.e., the consumers.

The SPV will cover the initial upfront capital expenditure (CAPEX) for the scheme, including the shared ambient loop array and the equipment inside the terraced homes. This is a model configured for those less able to pay or homes in poverty whereby the upfront capital normally required for building efficiency measures and low-carbon heat systems does not have to be covered or borrowed by the householder. It may also prove the most attractive model for the able-to-pay market.

The SPV may also make additional investments in offsite community generation, which can be procured under a PPA to deliver energy under a local energy model. The costs for the operation and metering, the maintenance and the replacement of the scheme will come from the SPV.

The SPV will recover these costs by charging the households participating in the Net Zero Terrace scheme a standing charge. The equipment inside the terraced homes is currently assumed to be owned by the households (i.e. ownership is transferred and not leased), and the standing charge payable by the residents will be used to pay off the cost of the equipment over the lifetime of the scheme. The standing charge will also cover all operational and maintenance costs associated with the scheme.

The upfront CAPEX of the rooftop PV and battery systems can be paid back in two ways. The model developed provides the option for individual households to have ownership of the rooftop PV system and to recover costs through the standing charge to the SPV. Under this model, the SPV would have rights to the electricity generated through the rooftop PV, which would be sold back to residents at a reduced rate as compared to standard market tariffs to encourage onsite renewable energy use. Any generation not used by the NZT residents and exported to the grid may then be sold against an export tariff which would provide the SPV with the opportunity to generate income. Any surplus revenue could be fed back to the scheme to reduce the standing charge, or bills for residents who are less able to pay. Alternatively, the SPV could retain ownership of the rooftop PV and recover the costs through electricity sales to the NZT residents and the grid. For use of their rooftops, the NZT residents would benefit from a reduced electricity tariff from the rooftop generation. A roof lease agreement may have to be in place for this mechanism, which may include lease charges in the model.

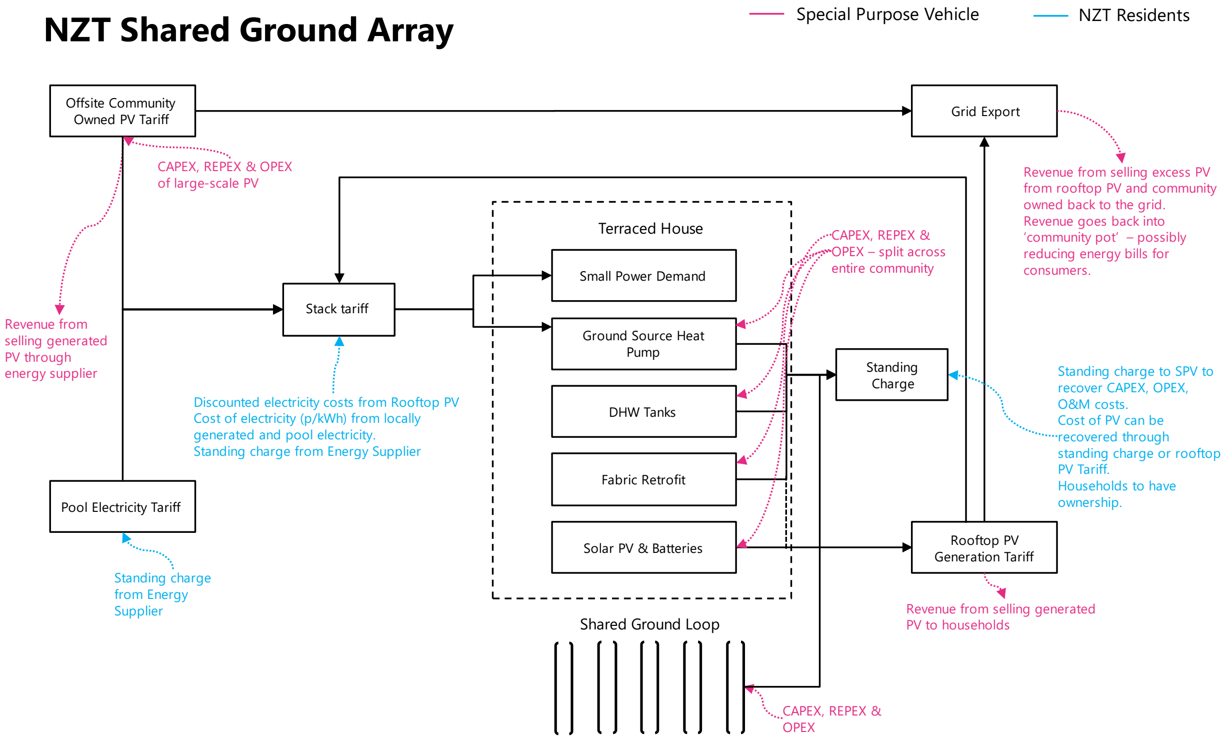

Figure 2-1: NZT Commercial Structure

Alongside the standing charge set to recover the capital and operational costs of the scheme, the NZT residents would pay a 'stacked' tariff for their electricity. This could consist of a tariff for the rooftop PV, a tariff for any offsite generation owned by the SPV and a tariff for the pool electricity procured through the energy supplier. These tariffs would be consolidated into one energy bill payable by the residents. The energy supplier will be responsible for sourcing renewable and low carbon generation and pooling these together to supply the NZT demand that is not met through the rooftop or offsite renewables. A standing charge would also be payable by the residents to the energy supplier to cover costs of procurement and management of the pool electricity and stack tariff. The offsite generation owned by the SPV would by managed through the energy supplier under a local energy model and the energy supplier would provide the SPV with export rates for the electricity generated. The NZT residents would use this generated electricity at discounted rate and any excess would be sold through the energy supplier at an increased rate.

2.2 Interdependencies

This design note covers the development of the techno-economic work package. However, other work packages provide input into the TEM and are mentioned below

When deploying at scale, the planning approach developed as part of the System Planning Approach work package will identify suitable cluster areas. The number of houses targeted will impact the economic viability of the scheme, with an increased uptake expected to reduce the costs of the scheme. And as the intention is for NZT to be deployed UK-wide, the location of the clusters may impact asset and labour costs. The System Planning Approach will also look to identify the rooftop PV capacity expected in an area and will be used to inform on any required electrical infrastructure upgrades, the cost of which will be captured in the TEM.

The energy model and TEM are closely interlinked, and the same scenarios will be modelled across both. The energy model provides the TEM with the estimated renewable generation and energy consumption for the terraced houses. It also determines the asset configuration and sizing in terms of energy storage requirements to deliver flexibility. The energy model will profile the expected rooftop PV generation consumed on site and other imports required to fulfil the terraced home demands. Flexibility will be modelled in the energy model and the economic impact will be calculated using the TEM. The TEM can be used to identify the economically optimum rooftop PV size and asset size and feedback to the energy model. This circular process forms the basis of the service model evaluation and will be eventually embedded into the planning workstream to optimise on system size and performance.

2.3 Scenarios

Various scenarios and economies of scale have been included in the techno economic modelling. This has allowed observations into customer bills and grant funding required if the scheme were deployed at various scales and has provided an indication into the minimum deployment require for the scheme to be economically feasible and self-sufficient. The purpose of modelling various scenarios is to test the model at both a 10-home demonstrator scale and a community scale. Modelling the various scenarios also allows for exploration of the sensitivities required to reduce the cost to consumers. A breakdown of the scenarios modelled are provided below however, these are discussed in more detail in Energy Model Design Note.

Scenario 1 – 10 Homes in Street A

The first scenario modelled focuses on deploying NZT to 10 homes. These homes act as the test demonstrator and indicate the costs required and the economic feasibility of the initial deployment of the scheme. Modelling 10 homes has allowed for accurate modelling of the energy demands, generation and flexibility capability. The 10 homes will also provide insight into the grant funding required for initial deployment to ensure consumers energy bills remain reasonable.

Scenario 2 – 103 Homes

The second scenario models the costs and energy demands associated with 103. This scenario demonstrates how costs begin to change at scale and the impact this has on the cost to consumer. This scale has partially been informed by the typical cluster size defined by Kensa for ambient loops.

Scenario 3 – 1000 Homes

The final scenario modelled provides an indication of the costs associated with the scheme and its economic feasibility when deployed at scale. Here the expected reduction in deployment costs per households can be observed.

Each of the 3 scenarios has been modelled with various levels of flexibility to explore how increasing flexibility changes the economic feasibility of the scheme. These levels of flexibility are discussed in detail in the Energy Model Design Note. However, a summary is shown below.

Scenario A – No Flexibility

In scenario A, 10, 103 and 1000 homes are modelled with no flexibility and the electricity imports from various sources are captured in the TEM.

Scenario B – Flexibility through use shifting

In scenario B, the energy model estimates the flexibility achievable for 10, 103 and 1000 homes through demand shifting and without battery storage. The imports and exports associated with this scenario have been modelled in the TEM.

Scenario C – Flexibility with Battery Energy Storage

In scenario C, a battery is added to the energy model for 10, 103 and 1000 and onsite consumption is prioritised. The CAPEX of the battery is captured in the TEM and the energy model provides the required grid imports. This scenario explores whether the benefit of utilising consumption onsite and decreasing grid imports outweigh the costs associated with the installation of a battery.

3 TEM Inputs

The TEM has been modelled with 2025 as the start year and over a 25-year period, which corresponds with the expected lifespan of the Heat Pump. The inputs for the Techno-economic model can be broken down in several categories. These include:

- Capital expenditure (CAPEX)
- Operational expenditure (OPEX)
- Replacement expenditure (REPEX)
- Energy tariffs and Usage
- Finance rates
- Grant Funding

These inputs vary for the different scenarios modelled and are discussed in more detail in the following sections.

3.1.1 Capital Expenditure

The capital expenditure is the initial cost required for the scheme's equipment. Table 3-1 shows a breakdown of the CAPEX used for the NZT Scheme.

Table 3-1 TEM CAPEX

Item	Cost/ Description	Reference
Heat pump and hot water tank	10 homes - £18,000 per home 103 homes - £15,600 per home 1000 homes - £14,4000 per home	Supplier quotations
Ambient loop network	10 homes - £12,000 per home 103 homes - £10,400 per home 1000 homes - £9,600 per home	Supplier quotations
Building fabric & retrofits	£12,000 per home	Estimates based on retrofit survey
Smart home equipment	£2,400 per home + 10% for installation and design contingencies	Supplier quotations
Rooftop PV panels	As show in Figure 4-4. 90% of system CAPEX	DESNZ and benchmarks
Solar Inverters	As shown in Figure 4-4. 10 % of system CAPEX	DESNZ and benchmarks
Battery energy storage	£2200 per battery	Supplier quotations
Connection Charges	£5000	Previous project experience
Design Costs	10% of CAPEX	Previous project experience

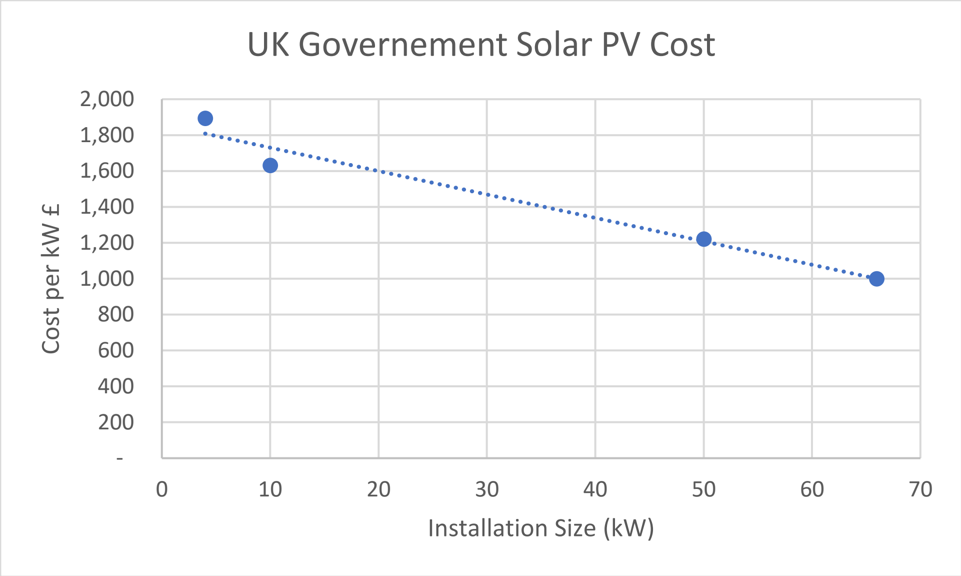

Figure 3-1 UK Government solar PV installation costs trend

Figure 3-1 shows the mean cost of solar published by the UK government[1]. The graph shows that the average cost per kW for solar PV decreases as the capacity installed increases. Solar PV prices have been seen to vary considerably over the last year or so; therefore, we have considered the use of benchmark data in the modelling as most appropriate for this stage. To capture the cost savings achieved through deploying at scale this cost database has been used to scale the cost of PV for each of the scenarios. It is assumed that the minimum cost for installing solar PV is £1000/kWp.

3.1.2 Operating Expenditure

The operational costs include the maintenance cost for the equipment and the costs associated with the set-up and operation of the scheme. Operational cost used have been taken from supplier and industry benchmarks where possible however, the costs provide are only intended to provide initial estimates. Costs will be refined further in subsequent project stages. Table 3-2 shows the operational costs modelled.

Table 3-2 TEM operating expenditure

Item	Cost
Equipment maintenance	1% of total CAPEX annually
SPV business/ administration	£100,000 annually per 10000 homes, pro-rated
Deployment Costs	
Community engagement – Pre deployment	£10,000 for initial cluster engagement
Community support – Post Deployment	£50,000 annually per 1000 homes, pro-rated
SPV set-up	£10,000
Community Energy Management	
Community Energy supplier administration	10% of annual energy sales turnover
CEMS Operator Administration Costs	5% of annual turnover
Fairer Warmth app maintenance	Minimum £2000 per community, 1000+ homes: £5 per home

[1] Solar_Costs_2022-23_Nov_23_update.xlsx (live.com)

3.1.3 Replacement Expenditure

The replacement expenditure is the cost of replacing system elements at the end of their functional lifespan. The cost of replacement is set to 80% of the CAPEX costs at year zero. The lifespan of the system installed is shown in Table 3-3. At the end of their lifespan, the systems will be replaced, with associated costs captured in the TEM. Replacement expenditure be recovered though either the standing charge or rooftop PV tariff.

Table 3-3 Lifespan of installed equipment

Component	Lifespan
Heat pump and hot water tank	25 years
Ambient loop network	25+ years
Building fabric & retrofits	25+ years
Smart home equipment	10 years
Rooftop PV panels	25 years
Solar Inverters	10 years
Battery energy storage	10 years

3.1.4 Energy Tariffs and Usage

Under the NZT scheme, various energy tariffs and standing charges are used under the NZT scheme. The tariff payable by the customer will depend on how the demand is being met. The energy usage for the different scenarios is detailed in the Energy Model Design Note and summarised in Table 3-4.

Table 3-4 NZT customer tariff structure

Item	Description	Paid by	Paid to
Energy supplier standing charge	Cost of standing charge to cover administration and metering from energy supplier	Customer	Energy supplier
CAPEX recovery standing charge	Cost of standing charged to recover equipment CAPEX	Customer	SPV
Rooftop PV import tariff	Cost of rooftop energy generated sold to the customer	Customer	SPV
Offsite SPV import tariff	Cost of offsite energy generated sold to the customer	Customer	Energy Supplier (Energy supplier then pays SPV)
Energy supplier tariff	Cost of electricity to customer imported from energy supplier	Customer	Energy supplier
Offsite PV export tariff	Revenue to SPV from selling offsite generation	Energy Supplier	SPV
Rooftop PV Grid Export tariff	Revenue to SPV for selling excess PV generated to the grid	Grid	SPV*

* The energy supplier may apply a billing administration charge and process this on behalf of the SPV

Some of the tariff costs will be determined using the TEM. Other tariffs are not flexible and will remain set across all scenarios. Table 3-5 shows the energy tariffs used in the TEM.

Table 3-5 Electricity Tariffs

Item	Tariff	Reference
Energy supplier standing charge	£900.33 Annually	Urban Chain*

CAPEX recovery standing charge	Calculated using TEM	
Rooftop PV tariff	Calculated using TEM	
Offsite SPV import tariff	Not currently used in TEM	
Energy supplier tariff	28p/kWh	Urban Chain
Offsite PV export tariff	Calculated using TEM	
Rooftop PV Grid Export tariff	4.1p/kWh	Smart export guarantee

- Other tariffs on the market may be used but for the purposes of initial modelling we have selected this tariff.

3.1.5 Finance Rates

The costs of borrowing the CAPEX will impact the profitability and payback times of the project. For this project, we have calculated the interest payments on an annuity basis that take into account the capital repayment and annual interest throughout the lifetime of the loan period an example of which is shown in Table 3-6.

Table 3-6 Finance rates

Item	Value	Reference
Interest rate	3.9%	Bank of England 2025 interest rate[2]

3.2 Grant Funding

In some instances, grant funding may be available to aid in the deployment of a scheme. For NZT the grant funding available through the boiler upgrade scheme has been accounted for in the modelling. The grant funding available can be seen in Table 3-7.

Table 3-7 NZT grant funding

Item	Value
Boiler Upgrade scheme[3]	£7500

3.3 Outputs

The outputs of the TEM will provide an indication of how the project preforms economically over its lifetime and the estimated revenue to the SPV. The TEM will also provide a cost to consumer for each of the scenarios modelled.

The purpose of the TEM is to provide a good benchmark on the cost to consumers and the potential return on investment to the SPV. These numbers are not suitable for investment proposals as there are many costs which cannot be confirmed at this stage of the project. The outputs for the project are shown in Table 3-8.

Table 3-8 TEM outputs for the project

Item	Description
Net Present Value (NPV) for SPV	Net Present Value of the project based on the cash flow over the lifetime of the project. Used to establish if the project is profitable through the lifespan of the project.
CAPEX Recovery Standing Charge	The standing charge required to recover the capital costs of the scheme will be calculated. The goal seek function will be used to calculate the minimum standing charge required.

[2] Monetary Policy Report - February 2024 | Bank of England
[3] Apply for the Boiler Upgrade Scheme: What you can get - GOV.UK (www.gov.uk)

Rooftop PV Tariff to NZT consumers	The rooftop PV tariff payable by NZT consumers will be established. Where the PV CAPEX is recovered through the rooftop tariff the goal seek function will be used to calculate the minimum tariff required.
Overall Cost to Consumer	The overall cost to the consumer will be made up of the standing charges and electricity tariffs calculated using the TEM and provide by external sources. Used to establish whether a reasonable cost to consumer can be achieved.

4 Workflows

The TEM and its workflows have been divided into different sections to determine the standing charge and energy tariffs, and the overall costs to the consumers and the SPV. The sections below detail the workflows for the different aspects.

4.1.1 Standing Charge

Figure 4-1 shows the workflow to calculate the CAPEX recovery standing charge. This is the standing charge payable by the households to the SPV to recover the cost of CAPEX for the equipment and for the operation and maintenance of the scheme.

As previously discussed, the equipment inside the terraced homes and the fabric retrofit will be owned by the individual households but the SPV will front the initial costs. The equipment costs will be split across the entire community and each household will pay the same standing charge regardless of the level of retrofit required. The rooftop PV and battery system can either be recovered through the standing charge or through the electricity tariffs. The total paid back for the equipment over the lifespan of the scheme will depend on the cost of borrowing and the payback period. Different plant items may be paid back over different timescales depending on the lifespan of the equipment or its origin. Also recovered by the standing charge are the operational and maintenance costs, including business costs and plant replacement costs.

These inputs combined will determine the standing charge payable by the households. However, this standing charge may be reduced by additional cash inputs. This could include grant funding, such as the boiler upgrade scheme. There may also be a revenue, or cash surplus once the consumers have paid their standing charge. This surplus, alongside any other income for the SPV, could form a ‘Community energy pot’ that could be feedback into the scheme to reduce the standing charge for households. Depending on the surplus this could be used to reduce bills for all households, or for households that are less able to pay.

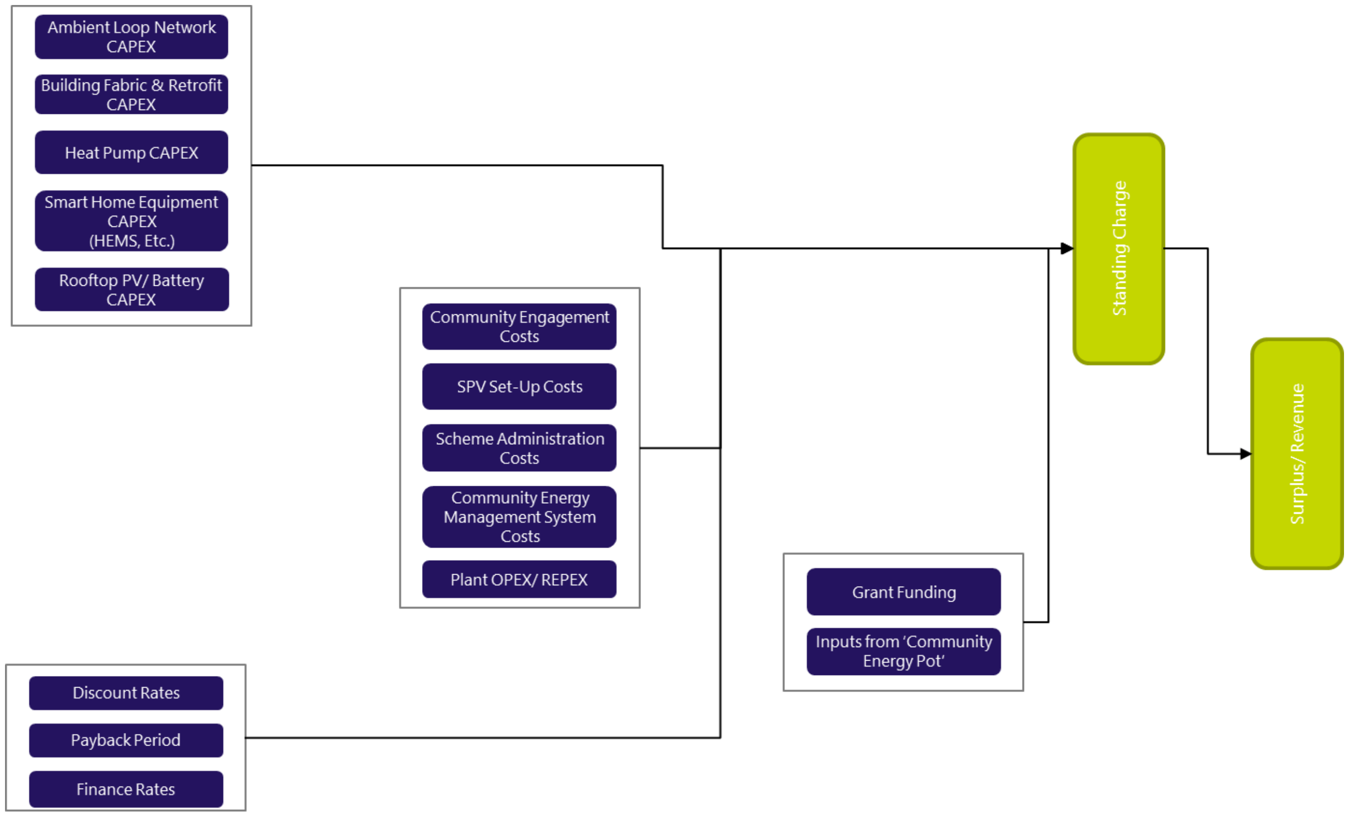

Figure 4-1 Standing Charge workflow

4.1.2 Rooftop PV Tariff

Figure 4-2 shows the workflow developed to calculate the required rooftop PV tariff. The rooftop PV and battery energy storage system CAPEX can either be recovered through the standing charge or through the rooftop PV tariff. If the CAPEX were to be recovered through the tariff, a reduction in standing charge and an increased tariff would be observed when compared to recovering the PV CAPEX through the standing charge.

Alongside the plant CAPEX, the amount of rooftop PV consumed or stored onsite will influence the required tariff. As the consumer tariff is expected to be higher than the export rate received from the grid, prioritising onsite consumption will generate more revenue for the SPV. Thus, providing the ability to reduce the consumers tariff while still covering the schemes costs. The rooftop PV generation consumed and stored by the NZT household is determined by the Energy Model.

The cost of finance, payback periods and discount rates used for the scheme will also influence the consumer tariff. Similar to the standing charge workflow, additional cash inputs, such as grant funding or inputs from the community energy pot, could reduce the tariff payable by the consumers.

Revenue is also generated through the rooftop PV tariff TEM by exporting any generation not used onsite to the grid. This additional revenue stream could be used to reduce the tariff for NZT households.

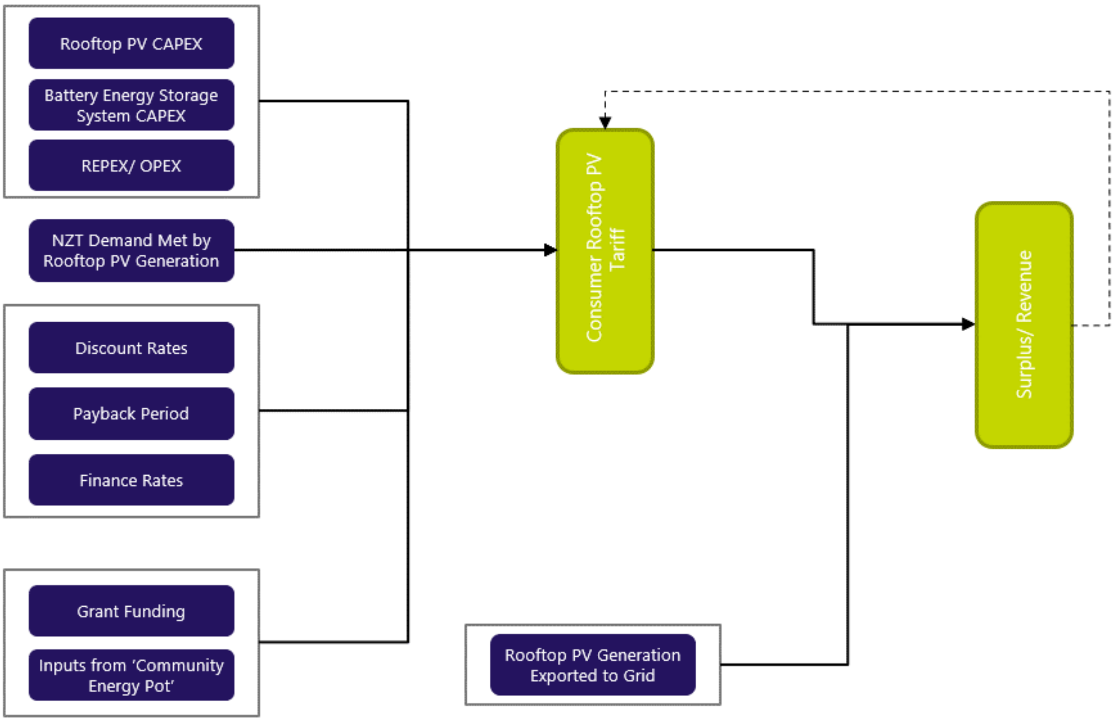

Figure 4-2 Workflow used to determine rooftop PV tariff

4.1.3 Cost to Consumer

Figure 4-3 shows how the final cost to consumer is calculated. Included in the final cost is the standing charge determined by the energy company and the standing charge required to recover the initial CAPEX costs. The electricity tariffs consist of the tariff provided by the energy company., the tariff for any offsite community renewable consumed and the rooftop PV tariff.

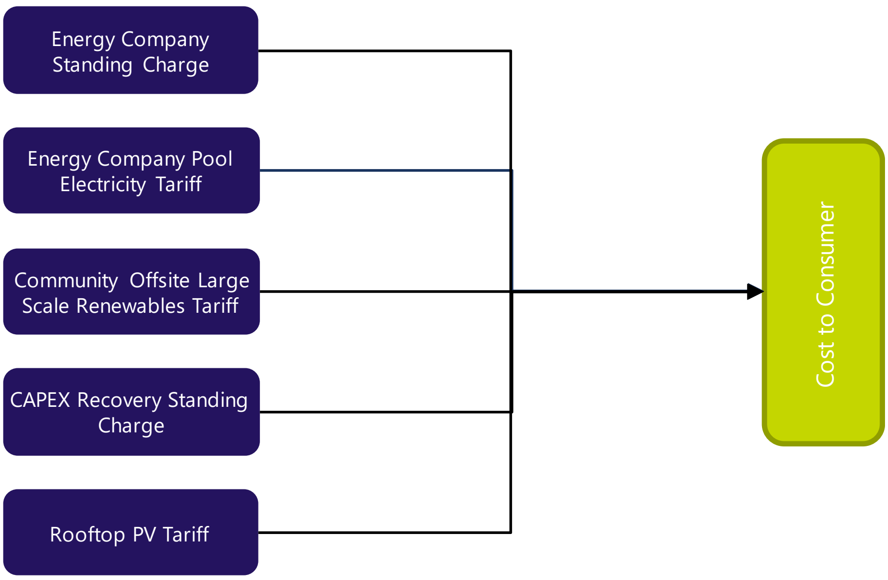

Figure 4-3 Cost to consumer workflow

4.1.4 SPV Costs and Revenue

Figure 4-4 shows the costs and revenues for the SPV. The costs include the initial CAPEX for the scheme, the operation and maintenance of the scheme, any other offsite community renewables deployed, and payments to the energy supplier for PV export management. These outgoing costs are recovered through revenue from rooftop PV generation sales, large scale renewables generation sales and revenue from the CAPEX recovery standing charge. Any excess cash observed after the outgoing costs are recovered will form a surplus. This surplus could be used to form a community energy pot that could reduce bills to NZT residents and consumers less able to pay. The community energy pot could also be used to fund the next deployment of NZT.

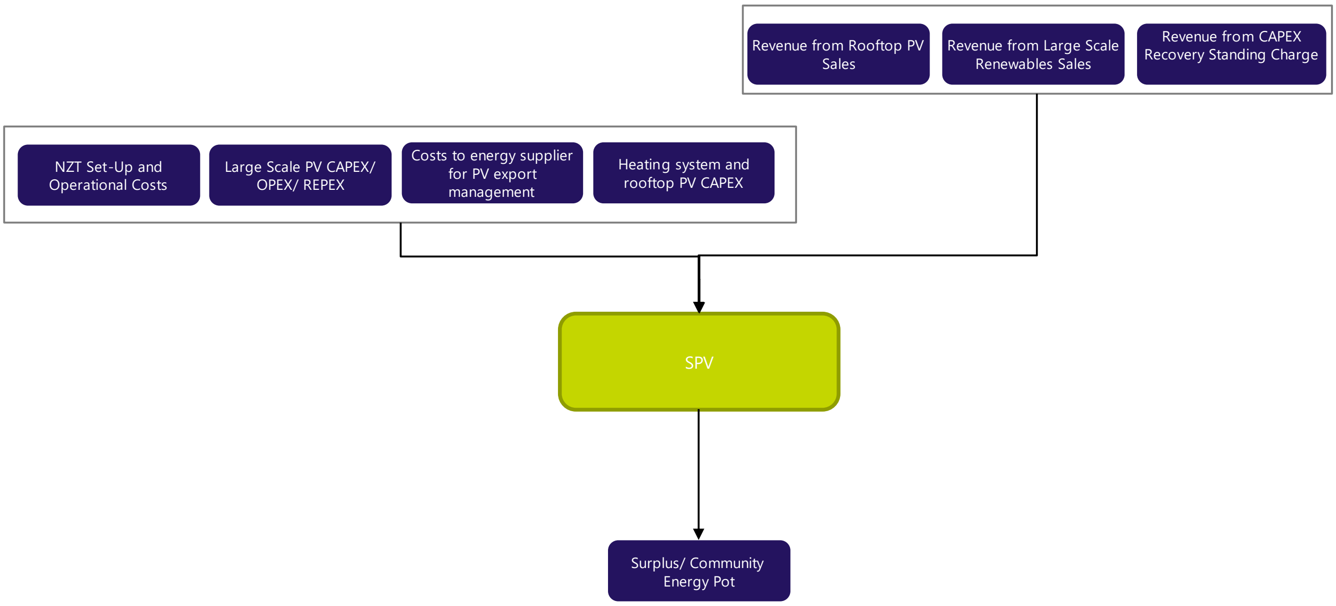

Figure 4-4 SPV costs and revenues

5 Results

The nine scenarios detailed in the above section have been modelled in the TEM and the outputs are discussed in this section. The modelling has looked to minimise costs to consumers while still recovering the capital and operational costs of the scheme i.e. we focus on affordability and a low NPV rather than a profit extraction model. This has been done using the goal seek function to calculate the minimum standing charge and rooftop PV tariff achievable while producing a positive NPV for the SPV. In each scenario the NPV has been set to £1000 for the standing charge cashflow and £1000 for the electricity sales cashflow, this provides a buffer to ensure the NPV of the scheme at the end of its lifetime is greater than zero. Future modelling could explore how the NPV could be increased and how this could be fed back as surplus to further reduce consumer energy bills or be used to support refinancing of the scheme to deliver lower costs in the future.

The results displayed from the TEM have assumed that the CAPEX for the rooftop PV and battery storage is recovered through the rooftop PV electricity sales and all other CAPEX and costs associated with the deployment of the NZT scheme are recovered through the standing charge.

5.1 Standing Charge

Table 5-1 provides the summary of the CAPEX recovery standing charge required for each scenario to achieve an NPV of £1000. The standing charge cashflow is explored in more detail in this section.

Table 5-1 Summary of Capex recovery standing charge required to achieved NPV of £1000

Scenario	Annual Standing Charge required to achieve NP of £1000
Scenario 1A (10 Homes, No flexibility)	£3,528.73
Scenario 1B (10 Homes, Flexibility in usage shifting)	£3,528.73
Scenario 1C (10 Homes, Flexibility through energy usage and battery usage)	£3,528.73
Scenario 2A (103 Homes, No flexibility)	£2,888.44
Scenario 2B (103 Homes, Flexibility in usage shifting)	£2,888.44
Scenario 2C (103 Homes, Flexibility through energy usage and battery usage)	£2,888.44
Scenario 3A (1000 Homes, No flexibility)	£2,717.30
Scenario 3B (1000 Homes, Flexibility in usage shifting)	£2,717.30
Scenario 3C (10000 Homes, Flexibility through energy usage and battery usage)	£2,717.30

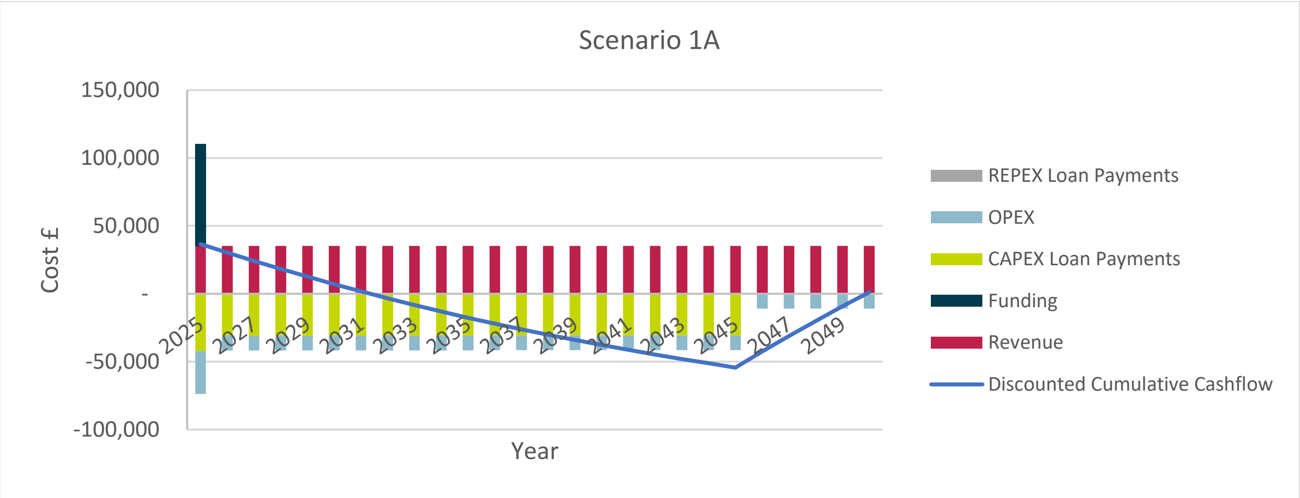

Figure 5-1 Standing Charge cashflow for Scenario 1a

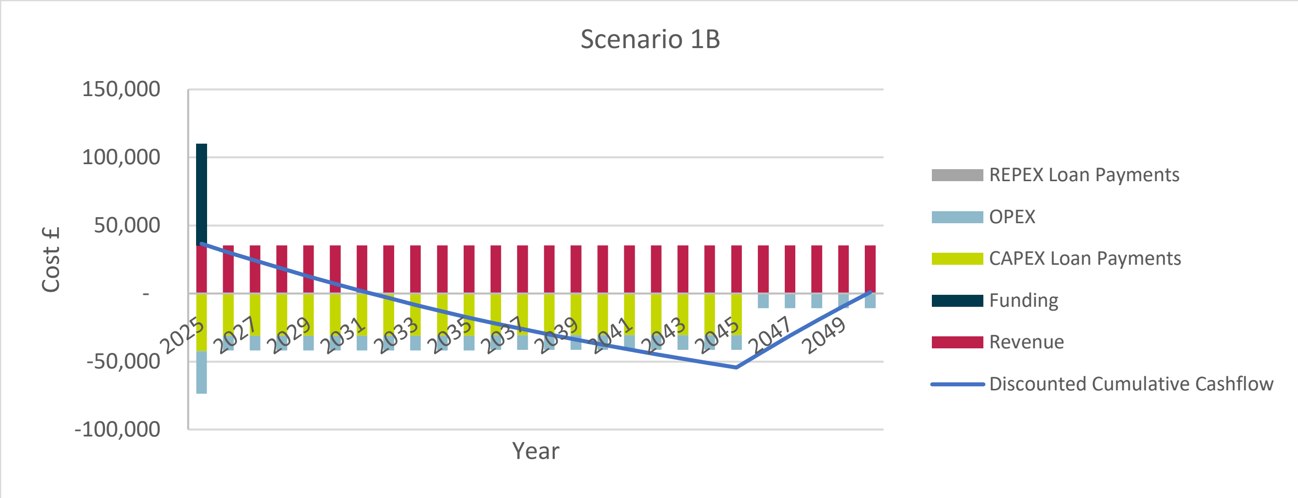

Figure 5-2 Standing Charge Cashflow for Scenario 1b

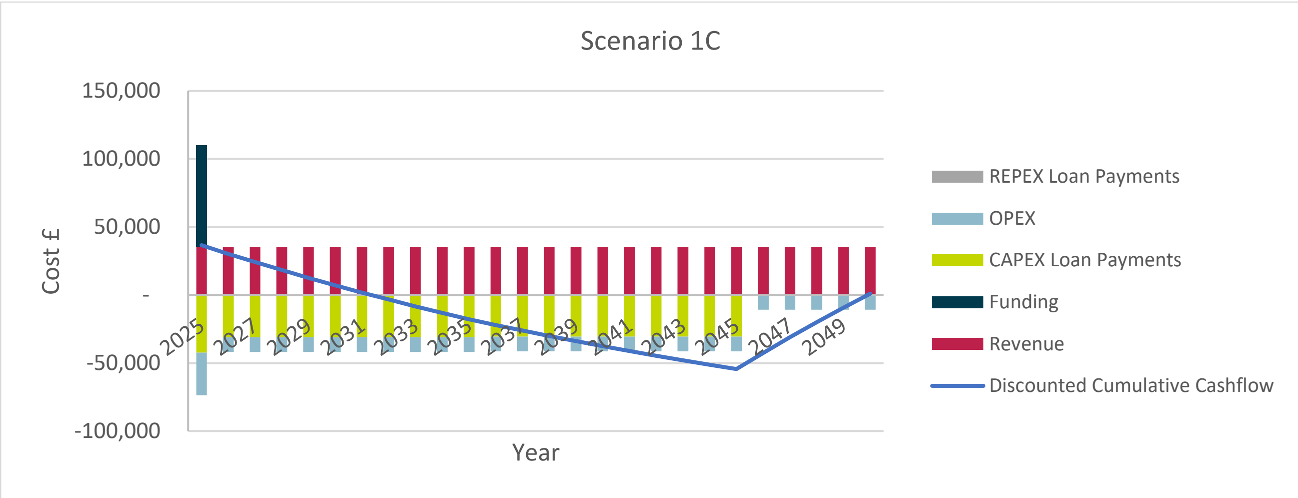

Figure 5-3 Standing Charge cashflow for Scenario 1c

Figure 5-1 to Figure 5-3 show the standing charge cashflow for 10 homes with different levels of flexibility. Each scenario has been modelled to provide a positive NPV at the end of the 15 years modelled for. For each of the flexibility scenarios modelled for the 10 home test demonstrator, a standing charge of £3,528.73 was required to recover the costs of the system CAPEX and operational costs. The discounted community cashflow trend line represents the profit or loss made each year by the scheme, a positive trend line indicates profit and a negative trend line indicates loss. For the 10 homes in Bacup the scheme does not begin to make a profit until all loan repayments have been paid off, at 20 years. This means the SPV would require a cash reserve to be able to maintain the scheme during its loss making years. The scheme becomes economically feasible when a positive discounted cumulative cashflow is observed. For the scenario modelled above this is at 25 years. This indicates that at the end of its lifespan the scheme makes a return on investment. The biggest outgoings associated with the NZT scheme are the CAPEX loan repayments. The initial investment required for the deployment of NZT is also significant. However, the remaining operating costs observed throughout the lifetime of the scheme are minimal compared to the CAPEX loan repayments. The grant funding provided by the boiler upgrade scheme ensures that the scheme's NPV remains positive for the first six years of operation.

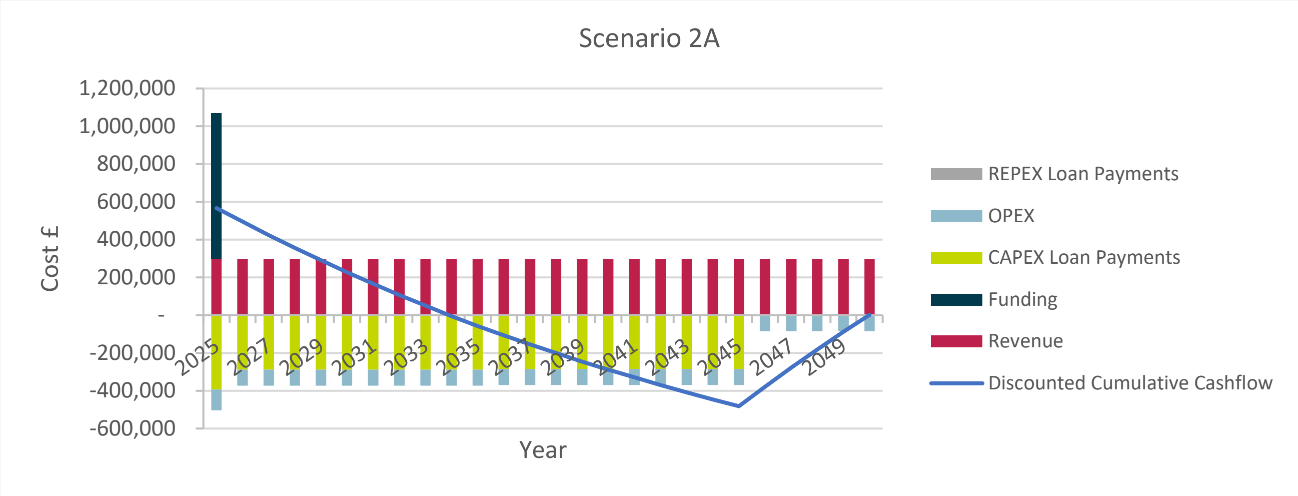

Figure 5-4 Standing Charge Cashflow for Scenario 2a

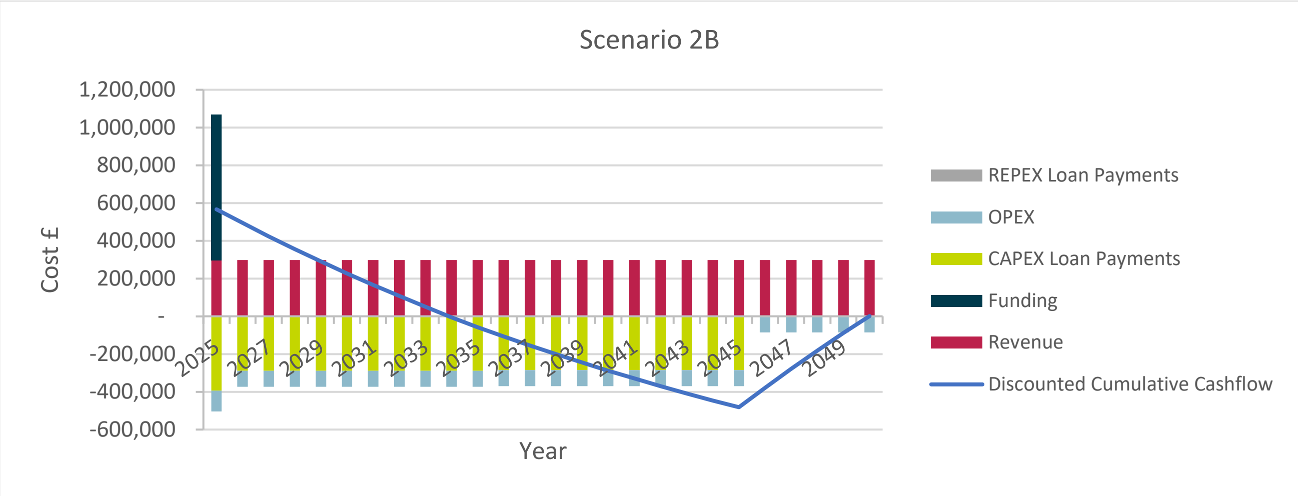

Figure 5-5 Standing Charge cashflow for Scenario 2b

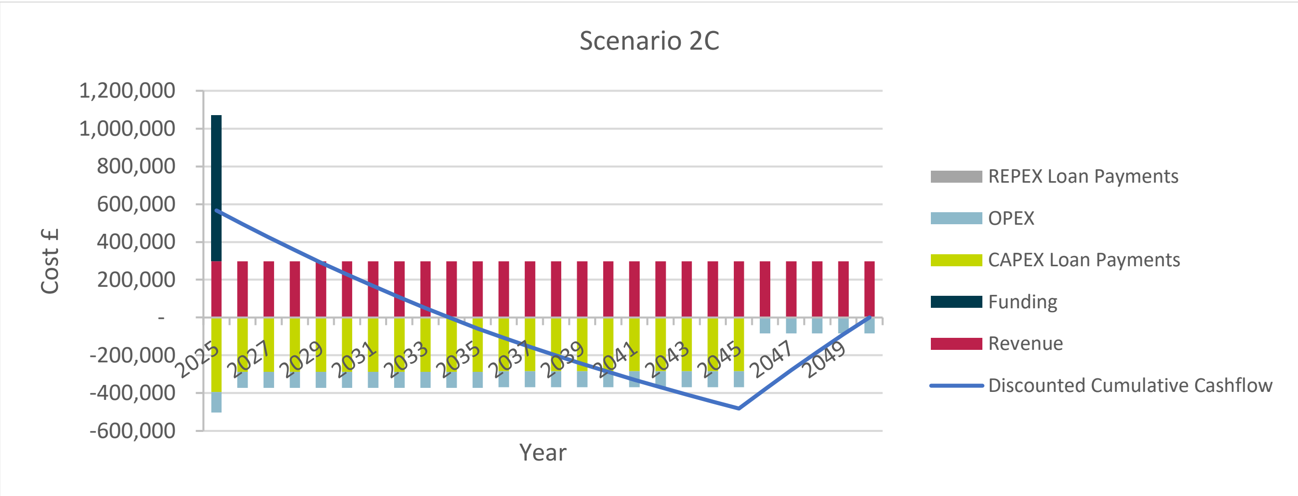

Figure 5-6 Standing Charge cashflow for scenario 2c

Figure 5-4 to Figure 5-6 display the cashflow over a 25-year life cycle for 103 with varying levels of flexibility. For all scenarios modelled for 103, a standing charge of £2,888.44 was required to achieve a positive NPV at 15 years. This provides a significant reduction on the standing charge required for 10 homes due to reductions in CAPEX observed through economy of scale. However, the SPV would still require a cash reserve to maintain the scheme until the scheme returns a positive NPV at year 25.

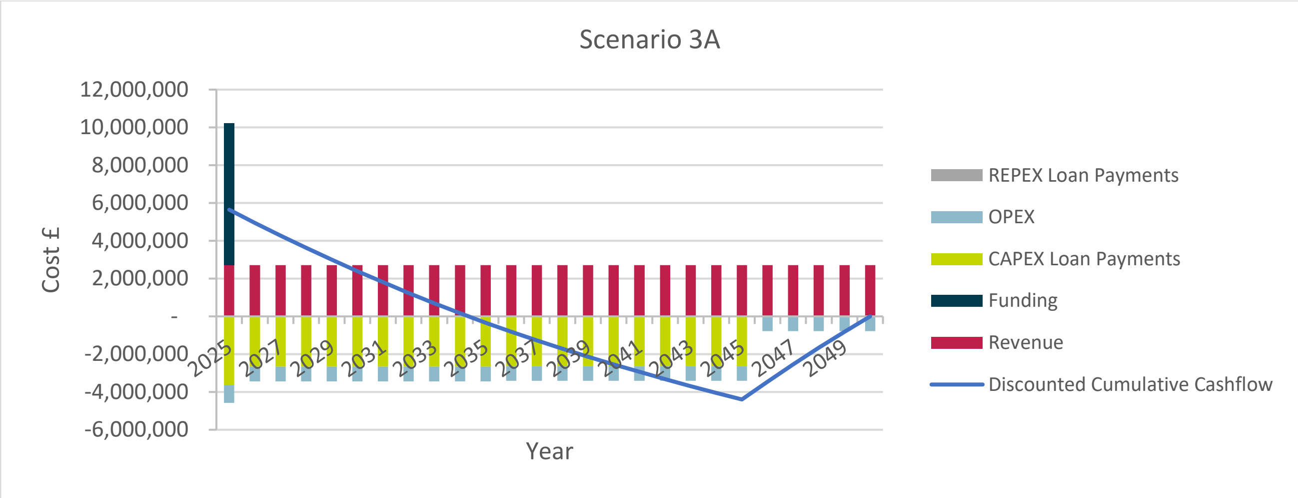

Figure 5-7 Standing Charge cashflow for scenario 3a

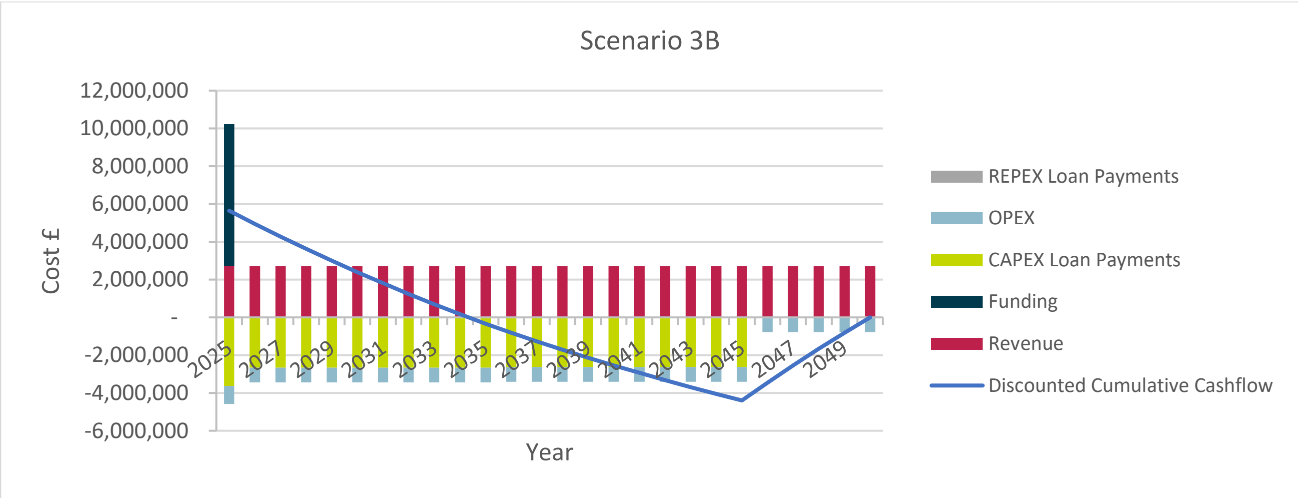

Figure 5-8 Standing Charge cashflow for scenario 3b

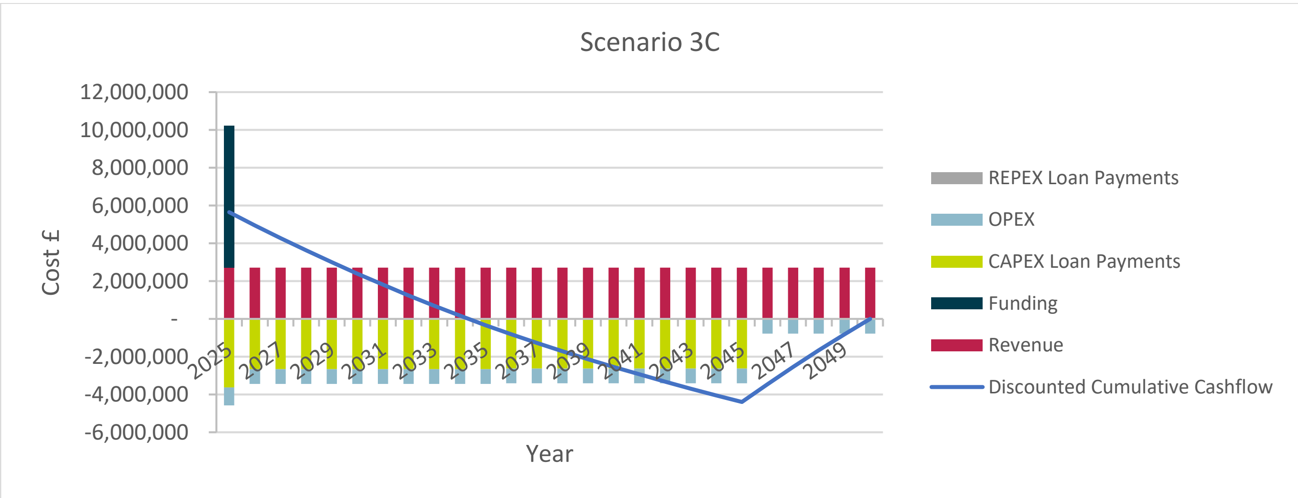

Figure 5-9 Standing Charge cash flow for scenario 3c

Figure 5-7 to Figure 5-9 shows the standing charge cashflow for the 1000 homes deployment scenario. For all flexibility scenarios a standing charge of £2,717.30 is required to recover costs and provide a positive NPV at 25 years. The costs and revenue associated with deploying at 1000 homes more accurately represents the costs expected for deployment at scale. The CAPEX loan repayments are still seen to be a significant contributor to the scheme's outgoing costs. Once the loan is repaid the scheme begins to turn over a revenue and a positive NPV is quickly achieved.

5.1.1 Conclusion

No difference in standing charge is observed with an increase in flexibility across the three scales of deployment modelled. Increasing the scale of the scheme significantly reduces the standing charge required to payback the system CAPEX as the benefits of economy of scale are realised. A significant reduction in the standing charge is observed between the 10 home test demonstrator and the 103 homes however, the savings achieved begin to reduce as the number of targeted homes increases from 103 to 1000 homes. The largest contributor to the standing charge is the system CAPEX repayments, and therefore methods to reduce this should be explored. This could be achieved with either a reduction in initial CAPEX cost through engaging with a broader range of suppliers or through exploring various loan providers with reduced interest rates, such as the UK Infrastructure Bank.

5.2 Electricity Sales

Table 5-2 provides a summary of the rooftop PV tariff required across each scenario to achieve a positive NPV at 25 years. In the modelled scenarios the rooftop PV tariff for NZT homes alongside the revenue achieved through sales to the grid is used to recover the rooftop PV systems CAPEX and operation and maintenance of the systems. The cashflows are discussed in more detail below. It is important to note that the rooftop PV tariff is not the only electricity tariff payable by consumers and the full cost to consumer is discussed in more detail in later sections.

Table 5-2 Summary of Rooftop PV tariff required to achieve NPV of £1000

Scenario	Rooftop PV Import rate to terraced homes required to achieve NPV of £1000
Scenario 1A (10 Homes, No flexibility)	19.5 p/kWh
Scenario 1B (10 Homes, Flexibility in usage shifting)	19.4 p/kWh
Scenario 1C (10 Homes, Flexibility through energy usage and battery usage)	32.7 p/kWh
Scenario 2A (103 Homes, No flexibility)	13.3 p/kWh
Scenario 2B (103 Homes, Flexibility in usage shifting)	13.2 p/kWh
Scenario 2C (103 Homes, Flexibility through energy usage and battery usage)	29.9 p/kWh
Scenario 3A (1000 Homes, No flexibility)	12.8 p/kWh
Scenario 3B (1000 Homes, Flexibility in usage shifting)	12.8 p/kWh
Scenario 3C (10000 Homes, Flexibility through energy usage and battery usage)	29.8 p/kWh
Average Green Book low cost of domestic electricity 2025-2050	11.3 p/kWh
Average Green Book central cost of domestic electricity 2025-2050	12.8 p/kWh
Average Green Book high cost of domestic electricity 2025-2050	15.3 p/kWh

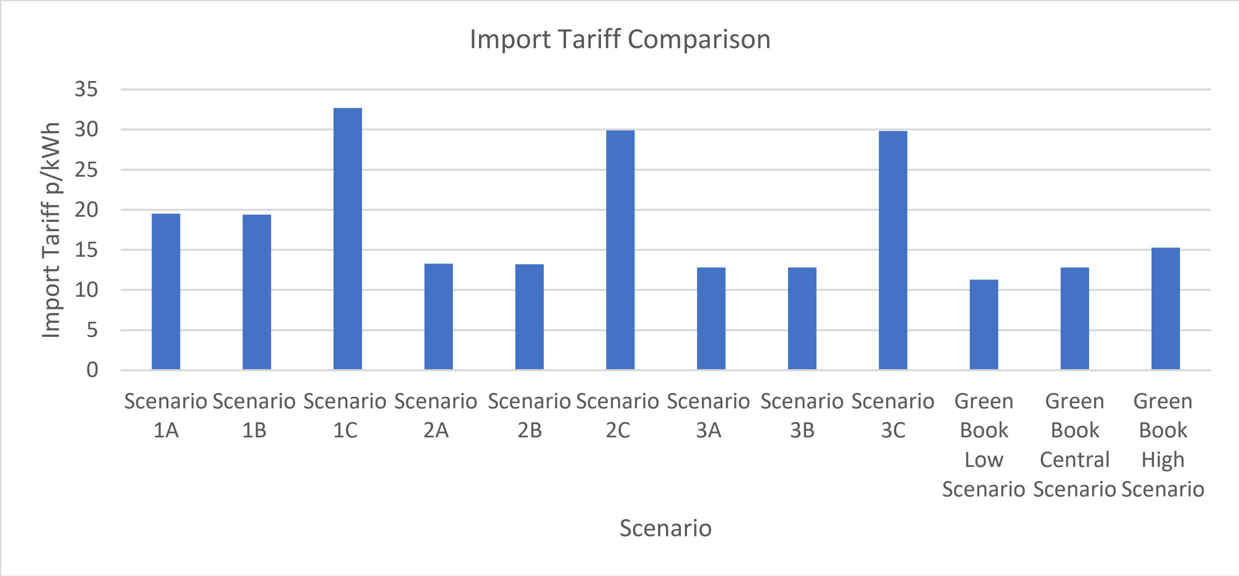

Figure 5-10 Electricity import tariff comparison

Figure 5-10 compares the rooftop PV import tariff calculate for each of the NZT scenarios with the average electricity cost estimates from the green book between 2025-2050. It is observed that many of the scenarios modelled are comparable with the energy cost estimated provided by the Green Book, indicating the economic feasibility of the scheme.

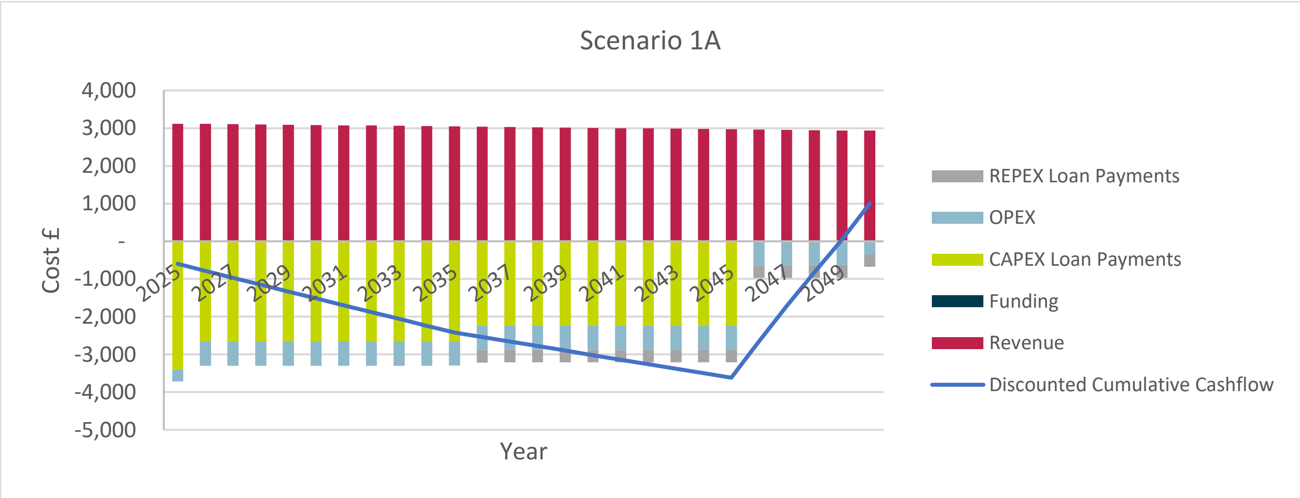

Figure 5-11 Electricity Sales cashflow for Scenario 1a

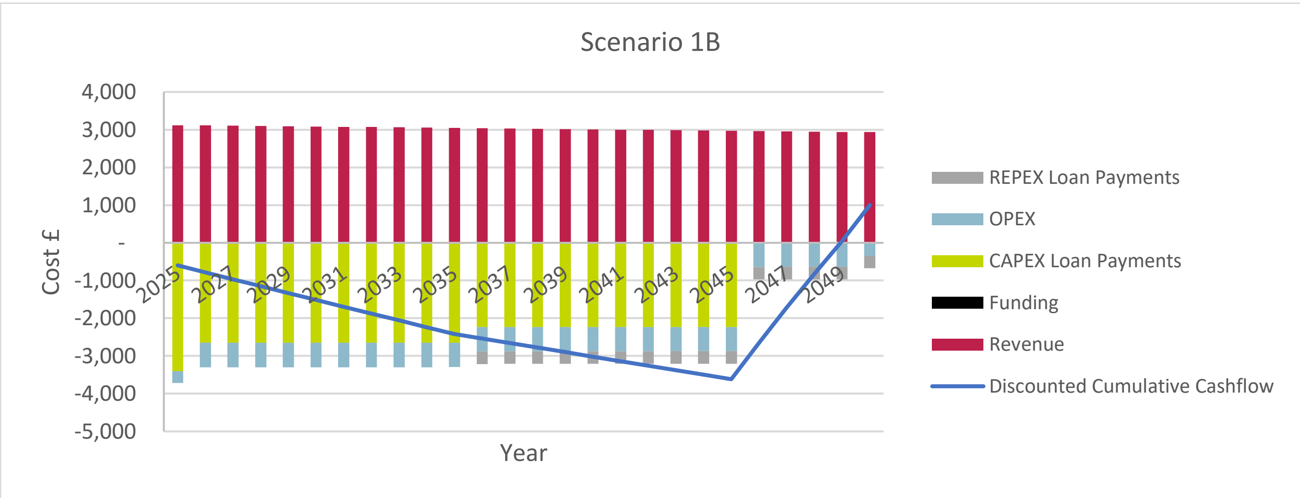

Figure 5-12 Electricity Sales cashflow for Scenario 1b

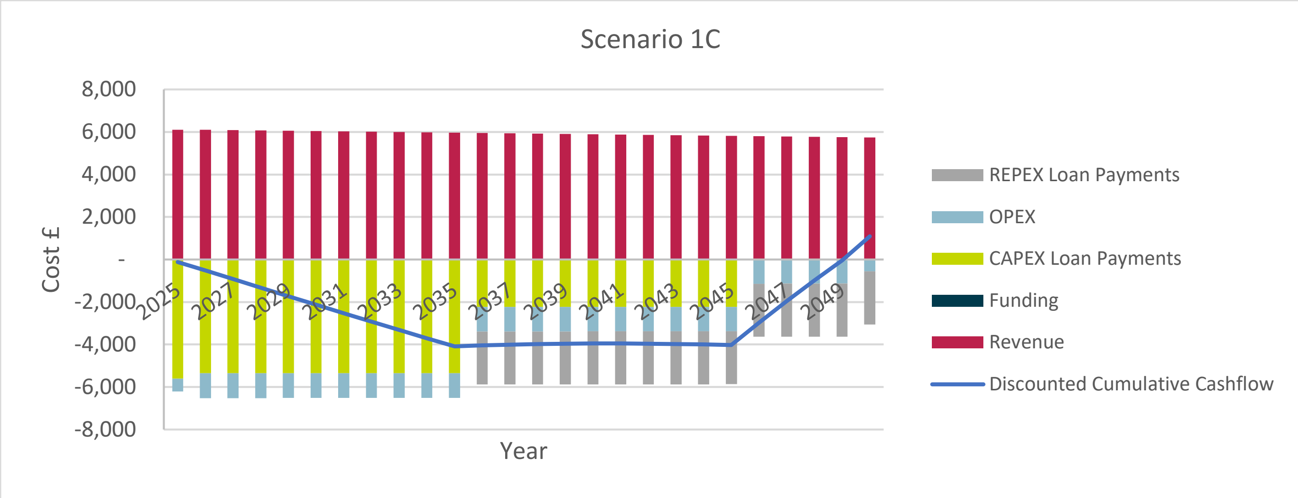

Figure 5-13 Electricity Sales cashflow for Scenario 1c

Figure 5-11 to Figure 5-13 shows the electricity sales cashflow for the 10 home test demonstrator. For scenario 1a and 1b the Capex loan payments contribute to a significant amount of the outgoing cost up until year 20. Once the initial CAPEX loan has been paid off the schemes begin to produce a positive cashflow and a positive NPV is achieved at the end of the scheme. The tariff to the terraced homes required to achieve this positive NPV is 19.5 p/kWh and 19.4 p/kWh for no flexibility and flexibility through f usage shifting, respectively. This is not significantly higher than the 15.3 p/kWh average high retail costs estimated by the Green Book between 2025-2050. A slight reduction in tariff is observed when flexibility through usage shifting is used due to the increase in rooftop PV used on sight.

The inclusion of battery energy storage changes the cashflow profile, as seen in Figure 5-13. Despite an increase in the rooftop PV utilised onsite, the CAPEX and the frequent replacement costs of the battery increase the energy tariff for the rooftop PV for the consumer. For scenario 1c the tariff required for terrace street exports to recover the system costs and achieve a positive NPV is 32.7 p/kWh. This is significantly higher than the high scenario electricity costs estimated by the Green Book.

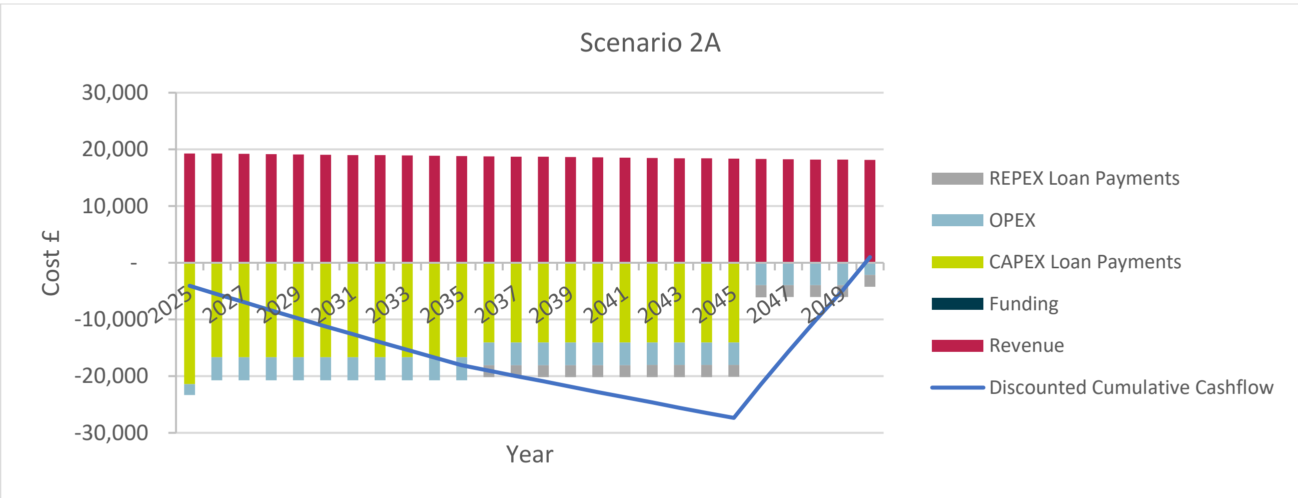

Figure 5-14 Electricity Sales cashflow for Scenario 2a

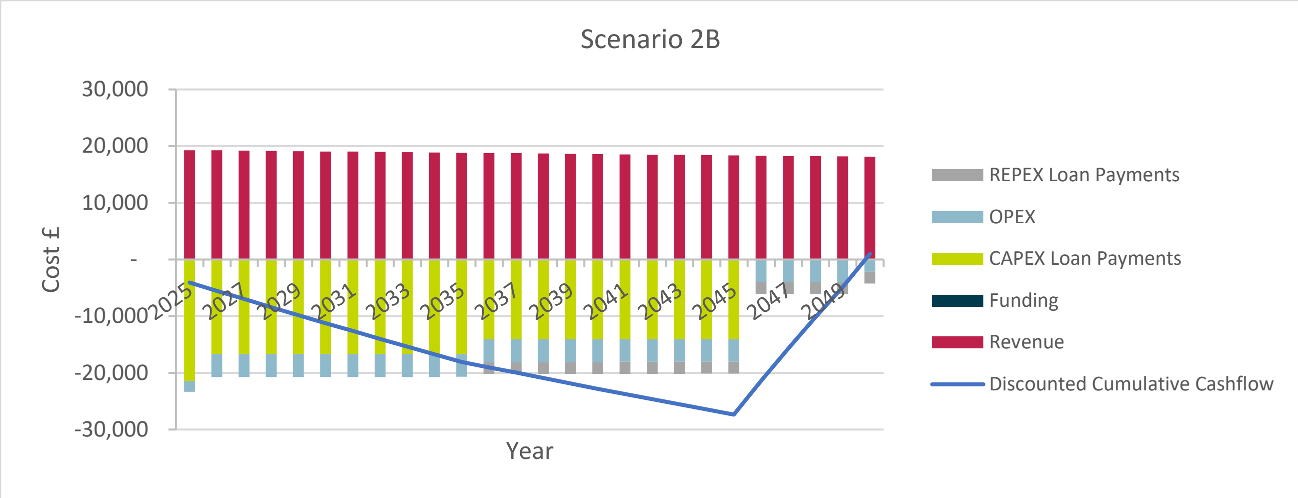

Figure 5-15 Electricity Sales cashflow for Scenario 2b

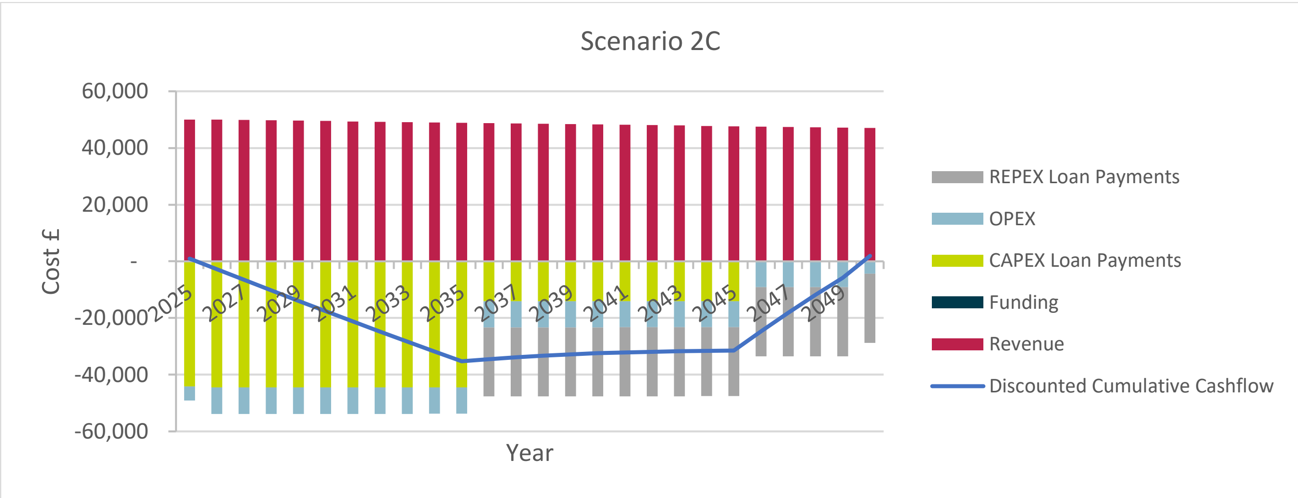

Figure 5-16 Electricity Sales cashflow for Scenario 2c

Figure 5-14 to Figure 5-16 display the electricity sales cashflow for the deployment of NZT to 103 homes with different levels of flexibility. Once again, an initial loss is seen for all scenarios as the CAPEX loan payments and operational expenditure exceed the revenue achieved from electricity sales. For scenario 2a and scenario 2b this loss is quickly recovered once the loan has been repaid. For each of the 103 homes scenario a significant cash reserve would be required by the SPV to maintain the scheme through the loss making year.
The tariff required to achieve a positive NPV at year 25 for scenario 2a and 2b is 13.3 p/kWh and 13.2 p/kWh, respectively. This is comparable to the 12.8 p/kWh central energy cost estimated by the green book for 2025 – 2050. Prioritising load shifting to achieve flexibility provides marginally savings to customer, as onsite consumption is prioritised.

The installation of a battery energy storage significantly increases the energy tariff required for the rooftop PV to 29.9 p/kWh. This is, in part, due to the replacement costs associated with the battery and because is a significant increase in onsite consumption is not observed.

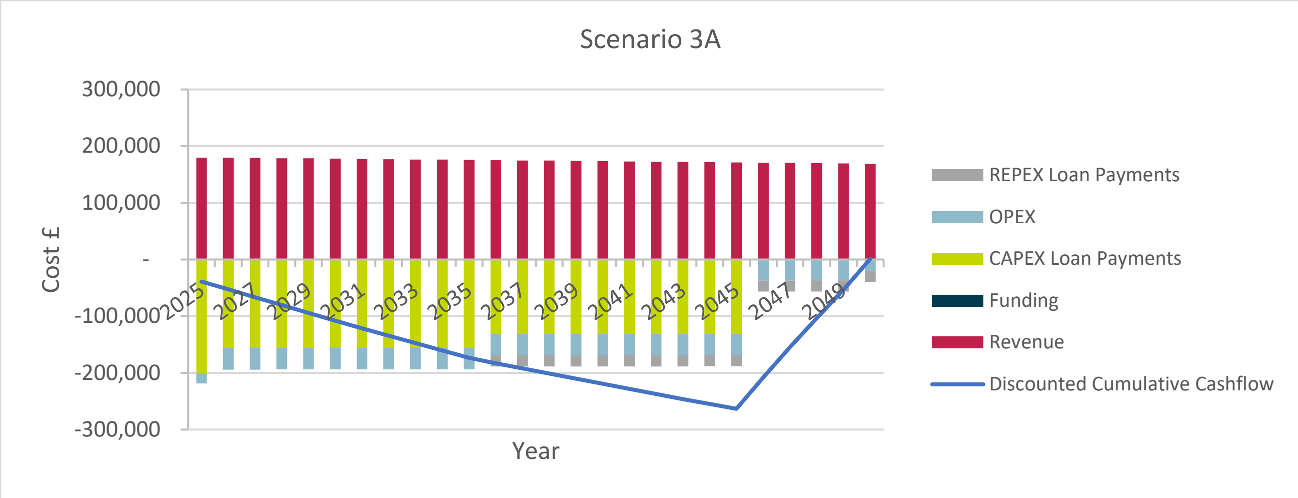

Figure 5-17 Electricity Sales cashflow for Scenario 3a

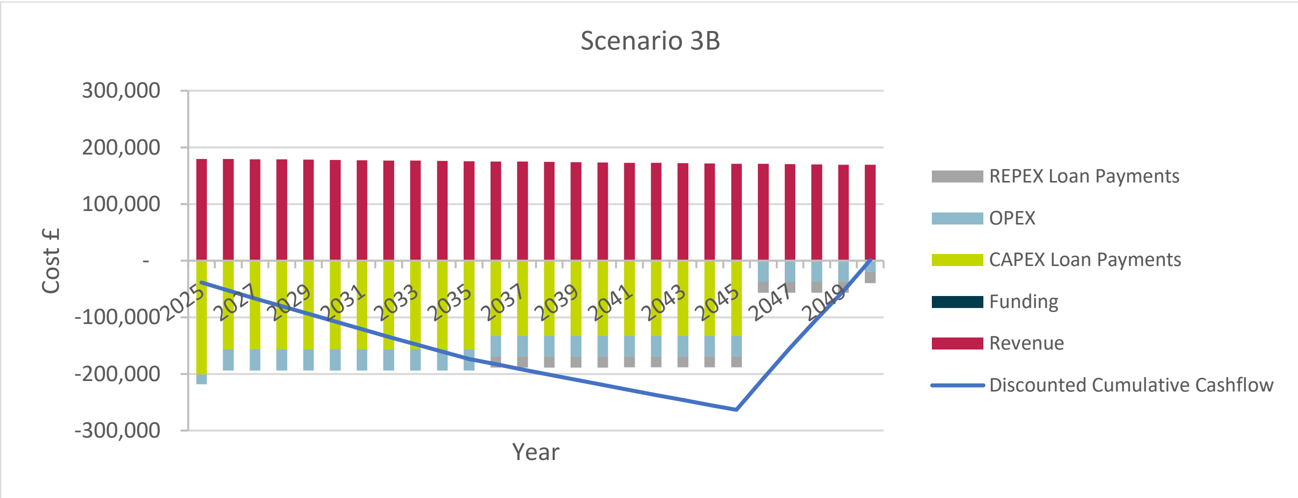

Figure 5-18 Electricity Sales cashflow for Scenario 3b

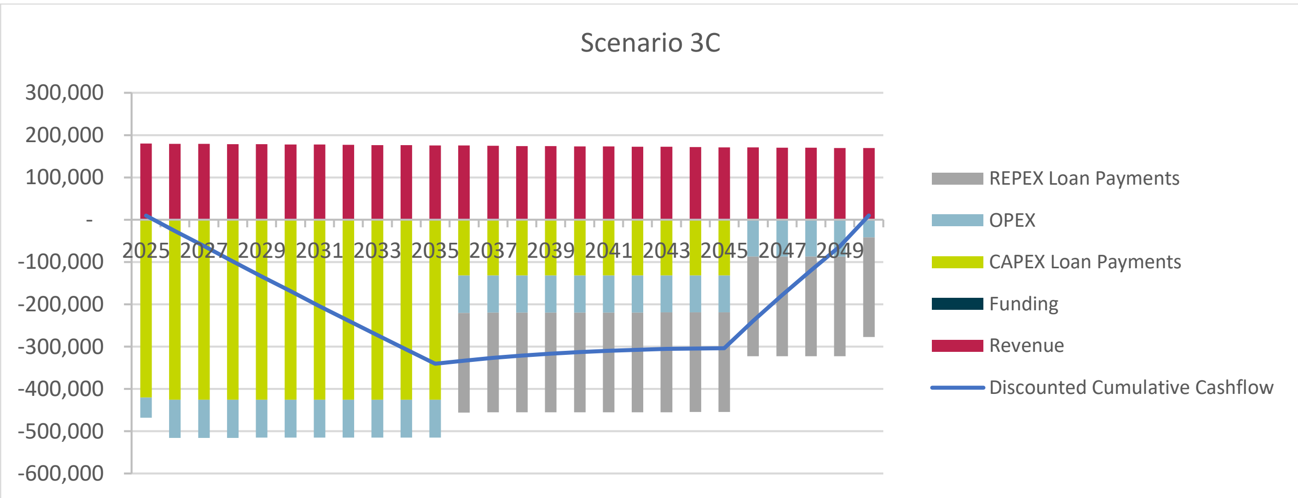

Figure 5-19 Electricity Sales cashflow for Scenario 3c

Figure 5-17 to Figure 5-19 shows the electricity sales cashflow for deploying NZT to 1000 homes at different levels of flexibility. The CAPEX repayments contribute to a significant proportion of the outgoing for the scheme and these are not recovered by the electricity sales in the early years of the scheme. Once the initial capital expenditure has been repaid a positive annual cashflow is observed before each scenario achieves a positive NPV at year 25.

No significant increase in onsite consumption is observed between 1000 homes with no flexibility and 1000 homes with demand flexibility. This is shown by the rooftop PV tariff required for each of the scenarios. Scenario 3a and 3b both require a tariff of 12.8 p/kWh to achieve a positive NPV. This matches the 12.8 p/kWh average of the green books central estimate for cost of electricity between 2025 – 2050.

The inclusion of battery storage increases the tariff required to achieve a positive NPV to 29.8 p/kWh. The increase in onsite consumption observed is limited and the benefits of battery energy storage for this scenario is yet to be realised.

5.2.1 Conclusion

A significant reduction in the electricity tariff required to achieve a positive NPV at year 25 is observed as the number of homes deployed to increases. This is in part, due to the reduction observed in the cost of Solar PV as the install capacity increase. For deployment to 103 and 1000 an electricity tariff comparable to the green book predictions can be achieved. The rooftop PV tariff achievable for the 10 home demonstrator is not significantly higher than those predicted by the Green Book and could still prove economically feasible.

A significant reduction in tariff is not observed between the no flexibility scenarios and the scenarios that achieve flexibility through demand shifting. A maximum reduction in 0.1 p/kWh is observed between the scenarios. More work should be conducted with the energy model to explore if onsite consumption could be further increased through demand shifting.

The benefits of battery storage are not realised in any of the scenarios modelled. The increase in capital expenditure and replacement costs observed is not counteracted by the increase in onsite consumption. The tariff required to achieve a positive NPV at 25 years with battery storage is, on average, an 15,6 p/kWh increase on the no flexibility tariff. Although individual battery storage is not likely to be economically feasible under the NZT scheme, the benefits of a community energy battery could be explored.

5.3 SPV Expenditure

Figure 5-20 to Figure 5-22 shows the SPV expenditure at year 5 for 10, 103 and 1000 across the different levels of flexibility. For each of the scenarios the CAPEX loan repayments are the largest proportion of the outgoing costs, with operational costs making up the second largest proportion. The majority of the outgoings costs for each scenario are recovered through the standing charge.

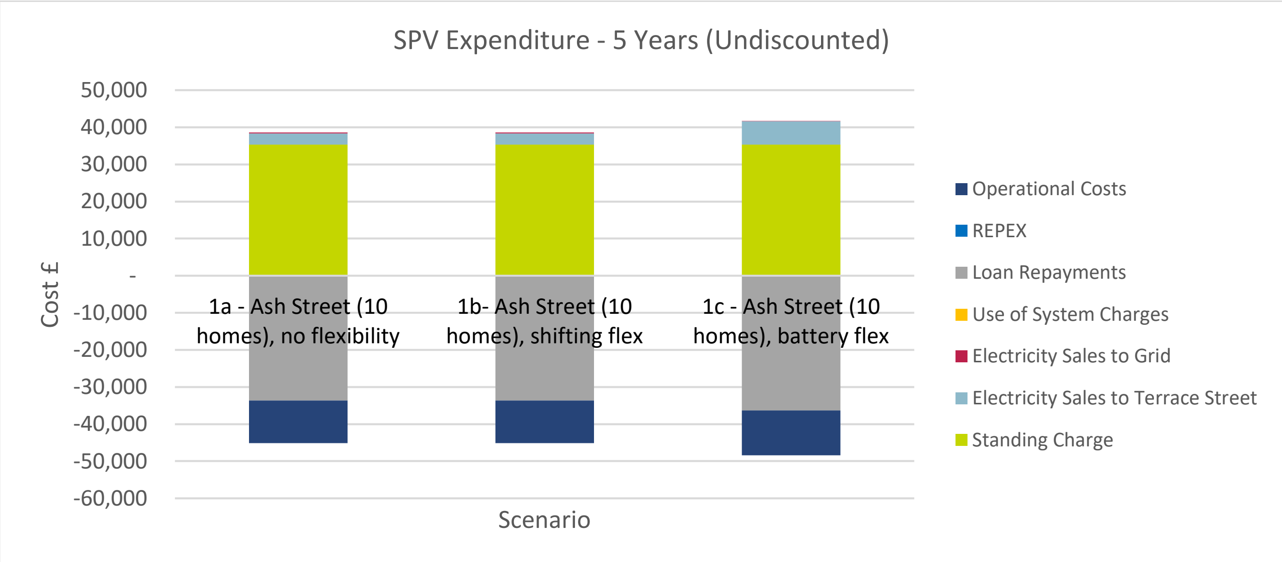

Figure 5-20 SPV Expenditure at year 5 for 10 homes

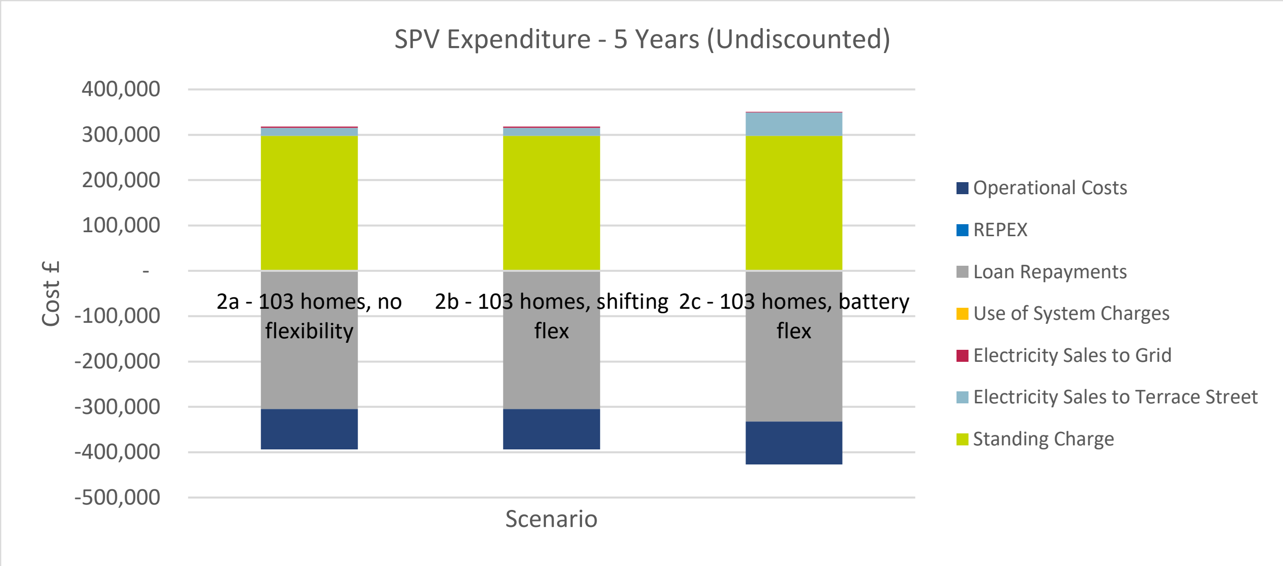

Figure 5-21 SPV Expenditure at year 5 for 103 homes

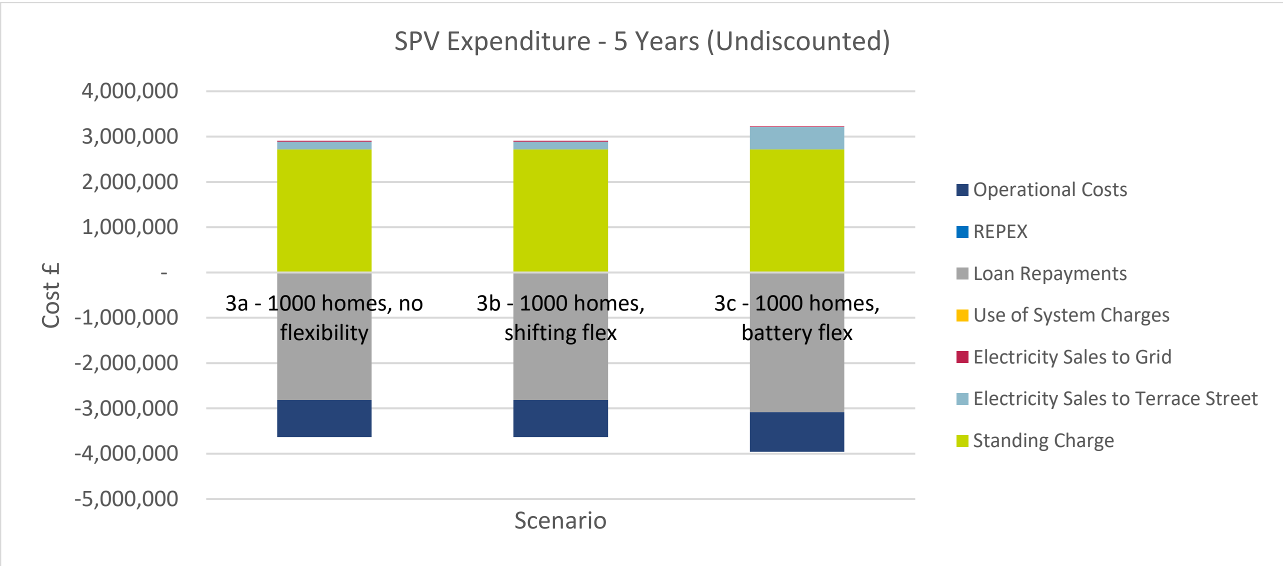

Figure 5-22 SPV Expenditure at year 5 for 1000 homes

5.4 Cost to consumer

One of the most significant outputs from the TEM is the overall costs to consumer. Each scenario has been modelled to provide the minimum costs to consumer while still providing an economically viable solution. A summary of the overall costs to consumers for each scenario is show in Table 5-3.

Table 5-3 Summary of overall costs to consumer

Scenario	Overall Cost to Consumer for NZT Deployment
Scenario 1A (10 Homes, No flexibility)	£5,700.63
Scenario 1B (10 Homes, Flexibility in usage shifting)	£5,698.52
Scenario 1C (10 Homes, Flexibility through energy usage and battery usage)	£5,910.50
Scenario 2A (103 Homes, No flexibility)	£4,703.56
Scenario 2B (103 Homes, Flexibility in usage shifting)	£4,702.21
Scenario 2C (103 Homes, Flexibility through energy usage and battery usage)	£4,912.08
Scenario 3A (1000 Homes, No flexibility)	£4,558.54
Scenario 3B (1000 Homes, Flexibility in usage shifting)	£4,558.39
Scenario 3C (10000 Homes, Flexibility through energy usage and battery usage)	£4,773.62

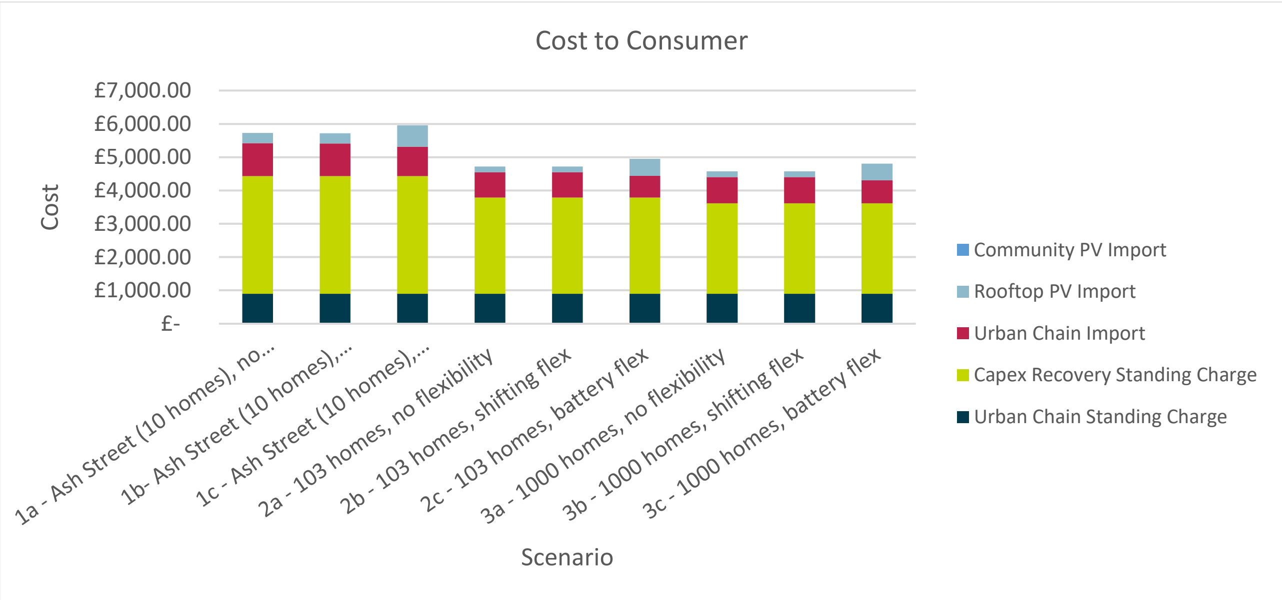

Figure 5-23 Cost to consumer breakdown across all scenarios modelled

Figure 5-23 provides a breakdown of elements fed into the overall cost to consumers and their contribution. The standing charges contribute the largest costs to the consumers, with the CAPEX recovery standing charge providing the most significant cost to the consumer. The imports tariff received from urban chain is the largest contributor to the electricity tariffs used. At 28 p/kWh this is significantly higher than the majority of the rooftop PV tariffs calculated by the TEM.

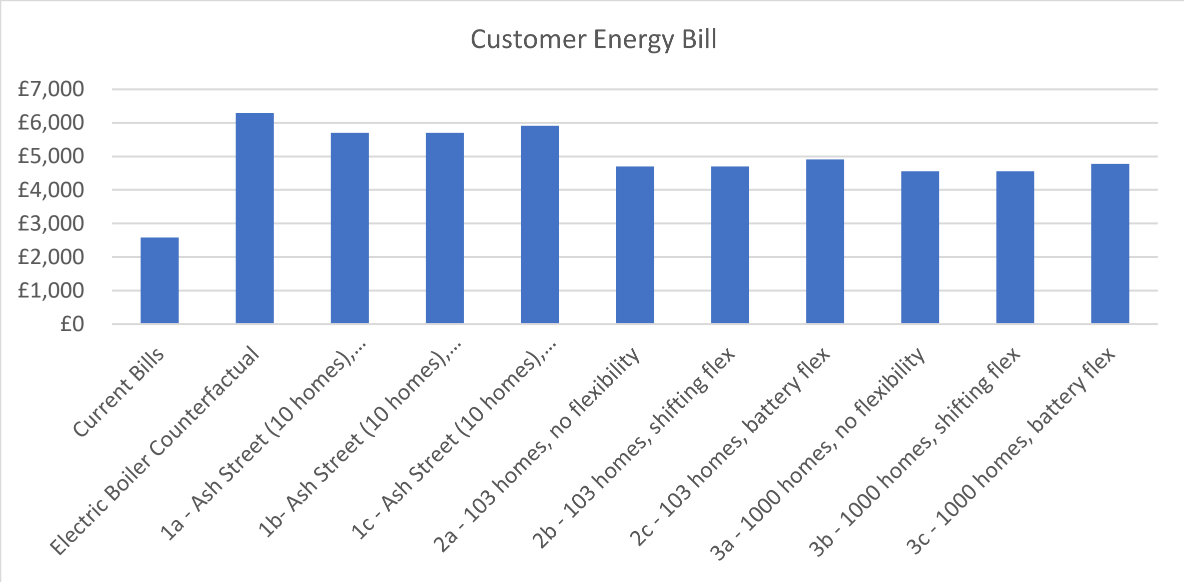

Figure 5-24 Customer energy bills comparison with current energy bills

Figure 5-24 shows the total cost to consumer for each scenario model and compares this to the consumers estimated current energy bills and the energy bills expected if an electrical boiler counterfactual was used. The current energy bills is taken as an average across the terrace homes in Rossendale from the energy bills data provided by parity. The cost of an electrical boiler contractual is calculated using the average energy demand for the terraced homes in Rossendale and using a coefficient of performance (COP) of 1. Energy bills for all scenarios modelled in the TEM are observed to be significantly higher than the consumers current energy bills. However, the contractual for de-carbonising terraced homes would be the installation of an electrical boiler and this results in consumer energy bills that are higher than any other NZT scenario modelled.

5.4.1 Conclusion

As we look to decarbonise homes and heating infrastructure the counterfactual to heat pumps and the NZT scheme will become electric boilers. When compared to the running costs of an electric boiler, all NZT scenarios modelled provided a reduction in energy costs for the consumer. This indicates that the NZT scheme could provide the most affordable option for the electrification of heat.

However, when compared to consumers current energy bills an increase in bills is observed with the deployment of NZT. A large contributor to this increase in energy bills is the standing charge rate required for the CAPEX payback. The standing charge and energy tariff provided by Urban Chain are also above what we would except in the current market and contribute significantly to the increase in consumer energy bills.

If net zero terraced is to be adopted by the community and provide an economically feasible solution to the community and SPV significant work is required in order to reduce the energy bills currently modelled in the TEM. Reductions in the tariffs offered by the energy supplier could be achieved by engaging with alternative energy companies to receive the best market rate. Methods for reducing the CAPEX recovery standing charge should also be investigated.

5.5 Reducing Cost to Consumer

The above sections have focused on calculating the costs to consumers based on input costs received from suppliers, industry benchmarks and government projects. It has been seen that with the current cost of CAPEX, finance and operational costs the scheme deployed to consumers cannot compete with their current energy prices. The purpose of Net Zero Terrace is to deliver a low carbon, affordable scheme to consumers and therefore, methods for deploying NZT with reduced energy bills must be explored. A Reduced Cost scenario has been modelled, which has looked at the conditions necessary to deploy NZT without significant increasing consumer energy bills. Table 5-4 compares the input costs the TEM for the standard model and for the optimised model, with justification for the updated values.

Table 5-4 Comparison of TEM inputs costs for deployment to 1000 home with the standard model and the reduced costs model

Item	Cost for Standard Model	Cost for Reduced Cost Model	Justification
Energy Company Standing Charge	£900.33 annually	£186.84 annually	Ofgem electricity standing charge price cap April – June 2024
Energy company Import Tariff	28.0 p/kWh	12.8 p/kWh	The Green Book average central electricity cost from 2025 - 2050
Cost of Finance	3.9%	3.5%	Available through UK Infrastructure Bank (UKIB)
Heat Pump and Ambient Loop Costs	£24,000	£20,000	Assuming reduction due to not for profit model.
Retrofit Costs	£12,000	£8,000	Low retrofit cost found in study
Smart Home Equipment Costs	£2640	£1000	Assuming discount due to economies of scale
Community Engagement Deployment Costs	£100,000	£50,000	Cost required to achieve target energy bills
SPV Business/ Administration Costs	£100,000	£50,000	Cost required to achieve target energy bills

Using the goal seek function to calculate the lowest cost achievable for the CAPEX Recovery Standing Charge and Rooftop PV import tariff while maintaining a positive NPV an updated cost to consumer has been calculated. The total cost to the consumer for the reduced scenario is £2,563.20, a breakdown of the costs is detailed in Table 5-5 below.

Table 5-5 Reduced Cost to Consumer breakdown

Item	Cost
Energy Company Standing Charge	£186.84 annually
Energy company Import Tariff	12.8 p/kWh
CAPEX Recovery Standing Charge	£1,897.85 annually
Rooftop PV Import Rate	10.5 p/kWh
Total Cost to Consumer	**£2,563.20**

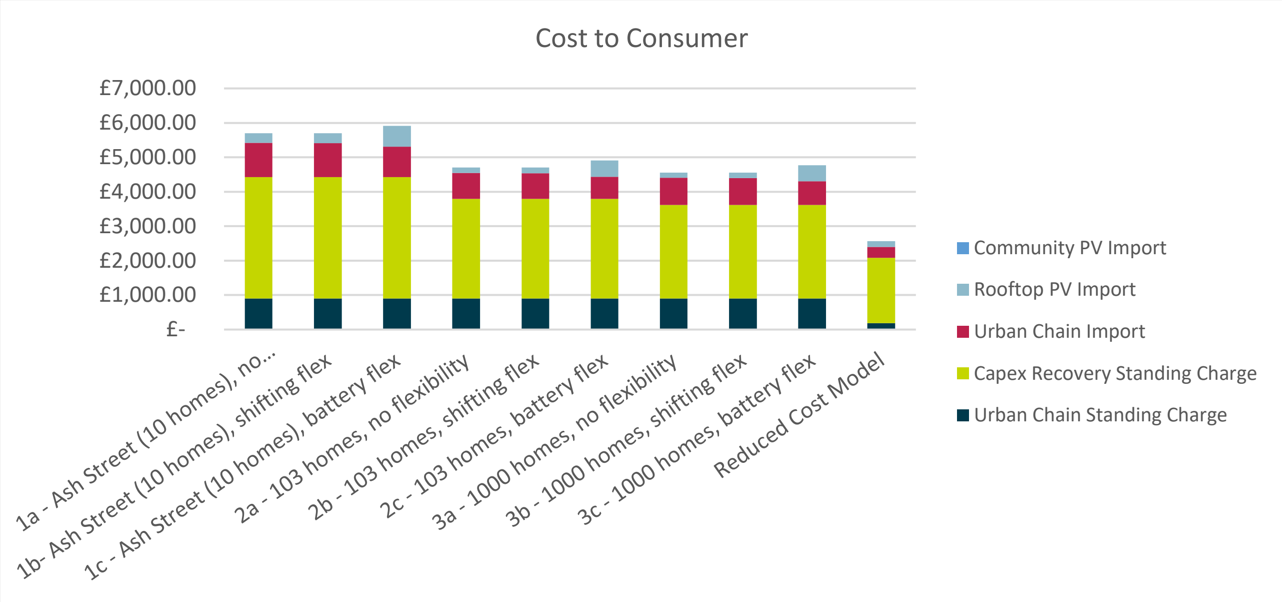

Figure 5-25 Cost to consumer comparison including reduced cost scenario

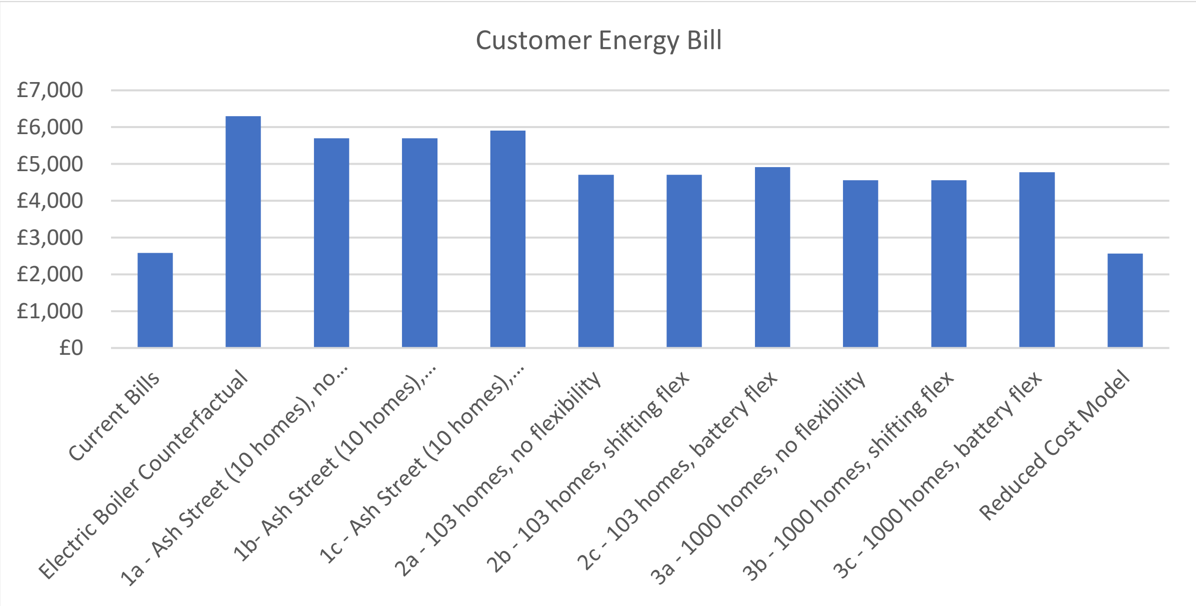

Figure 5-26 Customer energy bills comparison including reduced cost scenario

Figure 5-25 and Figure 5-26 shows how the reduced cost scenario modelled compares to the previously modelled scenarios and the current energy bills estimate. The reduced cost scenario provides a significant reduction in the overall cost to consumer, at £2,563.20 annually. This is comparable to the estimated current consumer energy bills of £2,579. The CAPEX recovery standing charge is still observed to be the largest contributor to the overall cost to consumers, however, this has decreased significantly from previously modelled scenarios.

5.5.1 Conclusion

It has been shown that NZT can be deployed at scale with an overall cost to consumer comparable to consumers current energy costs if work is done to reduce the inputs to and overheads of the scheme. Sourcing an improved rate of finance, from UKIB for example, would contribute to a reduction in the CAPEX recovery standing charge along with sourcing lower capital costs for the system installed. Exploring alternative energy companies to work with could reduce the energy company standing charge and import tariff, providing an overall reduced cost to consumers.

6 Conclusions and Next Steps

Under Net Zero Terrace Alpha a techno economic model has been developed to assess the economic feasibility and sensitivities to commercially deploy the scheme. Commercial structures and workflows have been developed to consider the cost of deployment to the SPV and consumers. In the workflows developed, the SPV fronts the initial capital costs for the system and the deployment of the scheme and these costs are recovered through a standing charge payable by the consumers. This forms one of the cashflows modelled in the TEM. The other cashflow model looks to calculate the import tariff payable by consumers from the rooftop PV generation to recover the CAPEX and operational costs of the PV.

The inputs to the TEM have been discussed in detail throughout this report and where possible these have been sourced from suppliers and energy companies. However, at this stage some costs are yet to be confirmed and have been used to test the outputs and the sensitivities of the model. To improve confidence in the modelling, reliable sources should be found for the assumed costs and further work could be conducted to engage with a range of suppliers to provide a broader range of inputs to allow for further sensitivity testing of the model.

Three economies of scale have been modelled to demonstrate the initial cost to deploy at a 10 home test demonstrator and the cost of deploying at scale. As the number of properties included in the scheme has increased the benefits of economies of scale have been realised. Increasing the number of properties from 10 to 1000 results in a significant reduction in the CAPEX per unit for the heat pumps and the solar PV installed. Increasing the number of households NZT is deployed to also reduces the overheads and administration costs required for the scheme's operation. During NZT alpha the model has been tested for 10, 103 and 1000 homes however, further work could be conducted to ensure the homes modelled provided an accurate representation of the area and work could be done to estimate the optimum number of homes for deployment.

Despite the NZT scheme providing an increased cost to consumers when compared to their estimated current energy bills, the feasibility of the scheme improves when compared to the counterfactual of an electrical boiler. As households decarbonise a move away from traditional gas boilers is essential and for space constrained terraced homes the alternative is an electric boiler. If an electrical boiler was installed to meet the heating demands of the terraced homes in Rossendale an average energy bill of £6,298 would be seen. This is a 38% increase on the cost to consumer calculated for deploying at 1000 homes with no flexibility. While electricity prices and the costs of low carbon technologies remain high competing with existing gas infrastructure proves difficult. However, when compared to other low carbon alternatives the NZT scheme becomes an increasingly attractive solution.

It was found that with all scenarios modelled the cost to consumers for deploying NZT was higher than their current energy bills. With building stock data used to define realistic energy bills for terraced homes in the area at approximately £2600 a year and the lowest bill calculated for NZT was £4,558.39. Increasing the scale of deployment was found to reduce the consumers energy bills somewhat, however, this was still considerable higher than the current estimated energy bills.

The largest contributor to the consumers energy bills was found to be the CAPEX recovery standing charge. This accounted for approximately 60% of the consumers energy bills in all scenarios modelled. Increasing the scale of deployment resulted in a 30% reduction in the CAPEX recovery standing charge as the benefits of economies of scale were realised. However, this still resulted in a significantly above average consumer energy bill.

The rooftop PV tariff calculated to recover the CAPEX and operational costs of the PV was found to be comparable with the Green Book price predictions for future energy prices. For deployment of scales of 103 and 1000 the scenarios modelled without a battery were found to produce a lower rooftop PV import tariff than the Green Books high energy costs scenario. If NZT were deployed at 1000 homes a rooftop PV import tariff of 12.8 p/kWh could be achieved, which is consistent with the Green Books central scenario. This indicates the economic feasibility of the deployment of rooftop PV to the terraced streets as the energy tariffs produced do not provide an increase on the market tariffs estimated to be available. The installation of rooftop PV would also offer some protection to consumers against the volatility of the energy market experienced in recent years and in some cases, a fixed tariff for the duration of the project could be set. This would result in a consistent and affordable import tariff for consumers. The inclusion of flexibility though demand shifting was not found to significantly reduce the import tariff to consumers and therefore future work should consider how flexibility could be increased and onsite consumption maximised. This would further reduce the import tariff for consumers. The inclusion of battery energy storage was seen to increase the import tariff by over 130% for each scenario modelled. This was as the increased CAPEX and replacement costs associated with the battery energy storage could not be recovered through the increase in onsite consumption. Future work could investigate the feasibility of the installation of a shared community battery. This would maximise onsite consumption and reduced the cost of installation per household.

The energy company standing charge and import rate were provided by Urban Chain, and these were found to be higher than expected. The standing charge of £2.47 a day provided by urban change contributed a significant amount to the overall bills to consumers. And the import tariff of 28 p/kWh is significantly higher than the rooftop PV import tariff found to be achievable. Future work should consider other energy suppliers able to provide similar services and market research should be conducted to provide a range of costs.

To compete with the prices paid by consumers today, an optimised NZT solution was modelled where optimistic costs estimates were used to reduce costs to consumers. Under the reduced cost model ways of reducing the current expenditure was explored and sources for reducing these costs were found. It was found that through acquiring a loan through UKIB the interest rate could be reduced by 0.4%, reducing the overall CAPEX repayment costs. Tariffs provided by Urban Chain were replaced with market rate standing charges and import tariffs, and low estimated for system CAPEX were considered. The reduced cost model proposed the operational costs that would be required to achieve a cost to consumers comparable with current energy prices. The modelling found an annual cost to consumer of £2,563.20 could be achieved with the above changes, comparable with the estimated current cost of £2,579. This suggests that a NZT scheme could be deployed where customer energy bills are not significantly increased. Future work should look to further test the sensitives around the TEM and source a broader range of inputs to ensure consumers receive the lowest cost possible.

To conclude, the techno-economic model work package has defined and presented commercial structures and workflows for the deployment of the NZT scheme. Inputs from the TEM have been where possible sourced from suppliers and government estimations however, at this stage these remain high level estimations. It was found that for the nine scenarios modelled consumer energy bills were significantly higher than the estimated current average, with the CAPEX recovery standing charge contributing to a significant proportion to this. However, when compared to the low carbon counterfactual of an electrical boiler the NZT scheme provided reduced costs to consumers. The installation of the rooftop PV was found to present an economically feasible case when compared the cost of energy estimated by the Green Book. And by optimising the model to reduce costs to consumers using optimistic inputs it was found that the NZT scheme could be deployed to consumers without increasing their current energy bills. Future work should look to obtain a broader and more accurate range of cost estimates to better test the models sensitivities. Methods for improving flexibility and the installation of a shared community owned battery should be explored to further reduce costs. Working with alternative energy companies could improve the standing charges and import rates payable by consumers and this should be further explored in future work.